THE GEOLOGY
AND
MINERAL RESOURCES
OF
ANNE ARUNDEL COUNTY

A DISSERTATION
Submitted to the Board of University Studies of The Johns Hopkins University
in conformity with the requirements for the degree of
Doctor of Philosophy

BY
HOMER PAYSON LITTLE

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BALTIMORE
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DEVELOPMENT OF KNOWLEDGE CONCERNING THE PHYSICAL FEATURES OF ANNE ARUNDEL COUNTY WITH BIBLIOGRAPHY

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HOMER P. LITTLE

Introductory

The first mention of the physical features of Anne Arundel County, as is the case with most of the region bordering on Chesapeake Bay, is found in Captain John Smith's account of his travels. This account is based on an exploration made in 1608, the results of which were published in London, in 1624, with other papers, under the title: "A Generall Historie of Virginia, New England, and the Summer Isles, etc." From that time to the present papers have been continually appearing which dealt either directly with the physical features of Anne Arundel County, or gave statements of a general nature which might be applied there as elsewhere. The most important of these will be briefly discussed in the following paragraphs, first those of a general bearing; then those which refer to particular geological horizons of the county beginning with the Potomac and proceeding successively up the scale through the Pleistocene; and lastly will be appended a bibliography of the publications consulted in the preparation of this report.

Historical Review

General contributions

As stated above, the first source of general information concerning Chesapeake Bay is to be found in Smith's "Generall Historie of Virginia,

New England, and the Summer Isles, etc." Smith's description of that part of the Coastal Plain which came under his observation is summarized by him as follows:

"The vesture of the earth in most places doth manifestly prove the nature of the soyle to be lusty and very rich. The color of the earth we found in divers places, resembleth bole Armoniac, terra sigillata ad Lemnia, Fuller's earth, marls, and divers other such appearances. But generally for the most part it is a black sandy mould, in some places a fat slimy clay, in other places a very barren gravel . . . . Thirtie leagues Northward [from the Patuxent] is a river not inhabited . . . .; for the red clay resembling bole Armoniac we called Bolus" [= Patapsco].

The next publication of real importance and one which is universally regarded a classic, is that of William Maclure, first printed in 1809 and republished with elaboration in 1817. This work is entitled "Observations on the Geology of the United States of America, with some remarks on the effect produced on the nature and fertility of soils by the decomposition of the different classes of rocks." A point of special interest is that this volume contains the first published geological map of the United States. As to the geology of the country, three divisions only are recognized: the Primitive, the Secondary or Transitional, and the Alluvial. In this last falls all the Coastal Plain of Maryland. Speaking of the origin of the Alluvial, Horace H. Hayden, in an interesting volume published in Baltimore, three years later, says:

"Viewing the subject in all its bearings, there is no circumstance that affords so strong an evidence of the cause of its formation as then that of its having been deposited by a general current which, at some unknown period, plowed impetuously across the whole continent of America, and that from northeast to southwest." Of further interest is the mention by the same author of the fossil remains of fish, terrapin, mollusca, and especially of the teeth of the Asiatic elephant, on the Western Shore of Maryland.

A most pronounced forward step was made in 1823 when John Finch, an Englishman traveling in America, made the suggestion in an oral

communication to the Philadelphia Academy of Natural Science "that what is termed the alluvial formation, in the geological papers of Messrs. Maclure and Cleaveland, is identical and contemporaneous with the newer secondary and tertiary formations of France, England, Egypt, and Hindoostan." The "Diluvial" is explained thus:

"After the production of these regular strata of sand, clay, and limestone, &c. came a terrible irruption of water from the north or northwest, which in many places covered the preceding formations, with diluvial gravel, and carried along with it those immense masses of granite, and of the older rocks, which attest to the present day the destruction and ruin of a former world."

The thirties and early forties saw, through the efforts of Morton, Say, Lea, and especially of Conrad, a continuation and pronounced refinement of the idea of correlation and nomenclature introduced by Finch. These men all collected and identified many fossils, the value of which from a geological standpoint had, up to that time, been inadequately recognized in this country. In 1828 Morton had published the notes of Professor Vanuxem in which the Cretaceous age of certain deposits was asserted; he continued to hold this idea although Eaton considered this "Ferruginous Sand Formation" as genuine Tertiary. Among the fossil forms cited by Morton in support of his view is "alcyonia" from "the greensand below Annapolis." In 1832 and 1833 Conrad published the description of a large number of Tertiary forms. In 1833 Lea published his "Contributions to Geology," in which the following important paragraph occurs:

"After a careful examination of a great number of genera and species from the Tertiary of Claiborne, Alabama, I had no hesitation in referring them to the same period as the London Clay of England, and the Calcaire Grossier of Paris .... This part of the Tertiary formation .... is called by Mr. Lyell the Eocene period."

Thus for the first time the term "Eocene" was applied to American deposits. Conrad, the following year, accepted the term and applied it at several localities, so that the name Eocene soon became firmly fixed in American literature. The same author, in 1838, proposed the classification

of the Tertiary into the Upper Tertiary (Newer Pliocene), the Medial Tertiary (Older Pliocene), and the Lower Tertiary (Eocene). The Medial Tertiary was correlated with the Crag of England which Conrad considered Older Pliocene. In 1841 he again correlated his Medial Tertiary with the Crag which, however, he was now convinced was Miocene. About this time Lyell referred to the Miocene of Maryland—for the term "Miocene" had already been applied to certain strata of Maryland in 1836 by W. B. Rogers and had been tentatively accepted by Ducatel—as more closely related to that of Lorraine and Bordeaux.

The term Pliocene, as now applied to the marine strata of the Atlantic Coast, was first used by Professor Michael Tuomey, in 1846. Post-Pliocene or Pleistocene, as applied to deposits of latest Tertiary age, was first used by H. D. Rogers, in 1844, in an address delivered at the meeting of the Association of American Geologists and Naturalists.

Thus by the end of 1846 there was introduced a nomenclature for the major divisions of the Mesozoic and Cenozoic of the Atlantic Coastal Plain similar to that employed at present, to wit: Cretaceous, Eocene, Miocene, Pliocene, and Pleistocene. The development of smaller subdivisions within each of these, beginning with the oldest, will now be discussed.

THE LOWER CRETACEOUS

This group of strata which rests on the ancient crystalline surface and extends to the marine beds above, was long recognized as belonging somewhere in the Jurasso-Cretaceous series, but whether entirely Jurassic in age, or in part Jurassic and in part Cretaceous, or whether entirely within the limits of the Cretaceous period, has been a debated question.

W. B. Rogers, in 1840, differentiated these deposits in Virginia from the older Mesozoic deposits to the west and called them Upper Secondary. Later he refers them "at least in part to the Upper Jurassic," and still later to the Jurasso-Cretaceous. Tyson, in 1860, recognized in the Cretaceous of Maryland a lower "group" consisting of sands and clays. In this lower group he differentiated the "iron ore clays" which Fontaine, in Monograph XV of the U. S. Geological Survey, made equivalent to his

Upper Potomac or "Variegated Clay Group." Professor Cook, in 1868, recognized that the Cretaceous of New Jersey could be divided by fossil content into several distinct series; the oldest of these he called the "Plastic Clay," and on the authority of Meek and Hayden referred it to the "Earlier Cretaceous." Conrad, in 1869, employed the name "Raritan" for certain of the lower beds in New Jersey, but the first use of the term as a formation name was by Clark in 1892 for the New Jersey deposits.

The term "Potomac formation," which is now used as a group name to include all the sands and clays of the Lower Cretaceous, was first suggested by McGee in 1885, who, on the ground that the flora was too unique to be definite, and because Marsh found the vertebrate remains to be distinctly Upper Jurassic, assigns the Potomac to that period.

McGee's term, "Potomac," was generally accepted and, since this series of deposits offered an attractive field of research, several workers were soon actively engaged in unravelling its stratigraphy. Fontaine, Uhler, Marsh, Ward, Darton, and somewhat later Clark and Bibbins, and Berry, all worked to a greater or less extent in this field, and each group of men entertained pronounced ideas as to the age of the group and the best system of nomenclature for its component parts. Fontaine, in Monograph XV, U. S. Geological Survey, on "The Potomac or Younger Mesozoic Flora," divided the "formation" into a Lower Member and an Upper or Variegated Clay "Group." Ward, in 1888, stated that he would not be surprised if the final verdict of science placed the lower plant-bearing horizons of the Potomac in the Jurassic, though he adds that "according to the ordinary method of arguing from similar statistics [proportion of dicotyledonous plants] the sum of all the facts here presented would make the Potomac, considered from the point of view of the flora alone, homotaxially equivalent to the Wealden of England and North Germany, now usually included in the Cretaceous system." In 1893-1894 the same author offered a detailed classification of the Potomac group of Maryland and Virginia as follows:

Newer Potomac	Upper Albirupean.
	Lower Albirupean.
Middle Potomac	Aquia Creek.
Basal Potomac	Mount Vernon.
	Rappahannock.
	James River.

All of these, with the possible exception of the Basal Potomac, were placed in the Cretaceous.

Uhler meanwhile had been carrying on investigations in Maryland, and in 1890 he classified the unconsolidated deposits below the marine Cretaceous into the "Potomac"—which he had formerly designated "Baltimorean"—the "Albirupean," and the "Alternate Clay Sands."

It will be noticed that much of the work referred to above, which placed part at least of the Potomac group in the Lower Cretaceous rather than in the Jurassic, had been carried on by paleobotanists. They based their conclusions on the relative abundance of monocotyledonous and dicotyledonous plants found in these deposits. In opposition to the paleobotanists stood the emphatic statement made by Marsh that investigations in the realm of vertebrate paleontology had "proved conclusively that the Potomac formation, as shown in its typical localities in Maryland, is of Upper Jurassic age." Clark and Bibbins, in 1897, proposed the following formation names and attempted to reconcile the conflicting views as follows:

Lower Cretaceous	Raritan formation	Potomac Group.
	Patapsco formation	
Upper Jurassic (?)	Arundel formation	
	Patuxent formation	

Later, in 1911 and again in 1916, in the Maryland cretaceous reports, Clark, Bibbins and Berry adopted the following interpretation based on the work of Berry on the floras and Lull on the dinosaurs.

Upper Cretaceous	Raritan.
Lower Cretaceous (Potomac Group)	Patapsco.
	Arundel.
	Patuxent.

THE UPPER CRETACEOUS

The Upper Cretaceous deposits of the Atlantic Coastal Plain had been little differentiated before 1868. In that year Professor George H. Cook published his important volume on the "Geology of New Jersey," in which he divided the Upper Cretaceous into two major series, each with several subdivisions. These major series were classified according to their economic uses and consisted of the "Clay Marl Series," overlain by the "Marl Series." A third series, the Plastic Clay, has been referred to in the discussion of the Lower Cretaceous. Cook's classification was not improved upon for many years, in fact not until after W. B. Clark began his work in 1891. In his final classification the Clay Marl series of Cook was practically unchanged in its limits, but the geographic term "Matawan" was substituted. Instead of the Marl series three geographic names of coordinate value with Matawan were employed, which in ascending order are: Monmouth, Rancocas, and Manasquan. Each of these is again divided into smaller units. Clark and his assistants traced the Cretaceous deposits southward into Maryland, where it was found that all the major divisions of the Cretaceous of New Jersey, except the Rancocas and Manasquan, could be readily identified. It was found impossible, however, to differentiate these into smaller units, as had been done northward, with the result that the group terms Matawan, Monmouth, and Rancocas of New Jersey become in Maryland formational names.

In 1893 Darton described "an arenaceous formation not hitherto discriminated, lying between the Potomac and Severn formations in the upper Chesapeake Bay region." This formation, which in its type locality corresponds closely with Uhler's Atlantic City Sands, Darton designated the Magothy formation. Until very recently this, with the formations of Clark described above, constituted the Upper Cretaceous of Maryland as generally accepted. In 1908, however, due to the work of Berry, the Raritan was separated from the Potomac group, making the Upper Cretaceous sequence of Maryland—Raritan, Magothy, Matawan, Monmouth, and Rancocas.

THE EOCENE

The Eocene, as already pointed out, was recognized as early as 1833. In spite of this, and in spite of the early development of a detailed classification in Alabama, the Eocene strata of the Middle Atlantic Slope were not subdivided for many years. Heilprin, in 1881, in a "Note on the Approximate Position of the Eocene Deposits of Maryland," pointed out the very close relation of *Ostrea compressirostra* and *Cucullæa onochela* with the European species *Ostrea bellavacina* and *Cucullæa crassatina*. He then says:

"If such observations are of any value stratigraphically we may fairly look upon the Maryland Eocene deposits—the Piscataway sands below and the Marlborough rocks above—as representing a horizon nearly equal to that of the Thanet Sands of England and the Bracheux sands of the Paris basin or of the British Bognor rock (= London Clay). In either case they would be near the base of the series." In the American succession he would place them as probably near the base of the Buhrstone or possibly even lower, the equivalent of the Eolignitic.

During the years immediately succeeding this Uhler published several notes on the Eocene of the Western Shore of Maryland.

Even at this date little really satisfactory knowledge of the Eocene of the region under discussion existed. It was indeed so meager that Clark, writing as late as 1891 in Bulletin 83 of the U. S. Geological Survey, said:

"The Eocene deposits of Maryland must be considered to represent a single horizon until a more detailed examination of the range of the different fossil forms affords evidence for a division upon that basis."

From this time on, however, rapid progress was made. Darton, in 1891, proposed the term "Pamunkey formation" for the Eocene. In 1895 Clark divided the Eocene into the "Aquia Creek Stage," in which he found a fauna "decidedly lignitic in character" and into the "Woodstock Stage" in which he found forms "identical or closely related to Claiborne types." Comparing these deposits with those of the Gulf region he says that he is "strongly of the opinion, upon both geological and paleontological grounds, that the Eocene deposits of the Middle

Atlantic slope represent the greater portion of the Eocene series of the Gulf, its highest members alone excepted." In a more extended memoir published the following year the same views are expressed. In 1901 Clark and Martin in a detailed report proposed the classification now used in Maryland. The Pamunkey formation was raised to the position of a group and within this two formations, the Nanjemoy and Aquia, were differentiated on both lithologic and faunal grounds. The Woodstock was relegated to the position of a substage resulting in the following divisions:

Group	Formations or Stages	Members or Substages
Pamunkey	Nanjemoy	Woodstock.
		Potapaco.
	Aquia	Paspotansa.
		Piscataway.

THE MIOCENE

The detailed classification of the Miocene, like that of the Eocene, was worked out largely during the years 1880-1905. As already pointed out, Conrad long considered what is now recognized as Miocene as the equivalent of the "Older Pliocene." Later, in 1841, he realized its true position, and here the matter rested for a long time. In 1863 Dana proposed the term "Yorktown epoch" to include the Miocene deposits of the Middle Atlantic Slope.

Heilprin, in 1880, after a careful study of fossils from the Miocene of Maryland, decided, on the basis of percentage of living forms, that these strata were of differing ages and could be divided into an "Older Period" and a "Newer Period." The latter was itself divided into the "Patuxent Group" and the "St. Mary's Group." In 1882 he presented a more complete classification for the entire Atlantic Slope as follows:

Upper Atlantic Miocene—the Carolinian Group. Represented by North and South Carolina deposits.

Middle Atlantic Miocene—the Virginia Group. Whole or most of the Virginia deposits and Maryland Newer Group.

Lower Atlantic Miocene—the Marylandian Group. The Maryland older Group and possibly the lower portion of the Virginia formation.

Darton, in 1891, referred the Miocene deposits of Maryland to one formation which he called the Chesapeake. This view was accepted by Dall and Harris in 1892.

In 1893 Harris made a report on detailed paleontological investigation along the Calvert Cliffs. He recognized there three separate faunas in ascending order, the "Plum Point fauna," the "Jones Wharf fauna," and the "St. Mary's fauna." Dall, in 1898, retained these divisions and correlated them with the Helvetian of Europe. Shattuck, in 1902, stated that three formations could be recognized each with well-defined lithologic and faunal characters. These he named the "Calvert," "Choptank," and "St. Mary's," and these three formations, united to form the "Chesapeake Group," constitute the Miocene of Maryland as at present understood.

In 1904 Clark, Shattuck, and Dall published a very detailed report on "The Miocene Deposits of Maryland," in which much additional data are given and many fossils described and illustrated.

THE PLIOCENE (?) AND PLEISTOCENE

For a long time the surficial deposits of the Coastal Plain were, when differentiated at all, grouped together under the head "Diluvial." The earlier geologists had only a vague idea of the manner of their formation; and owing to the character of the materials, which promised little in the way of fossil evidence, almost no attempt was made to classify them. H. D. Rogers, in 1844, first used the term "post-Pliocene or Pleistocene" for these deposits of latest Tertiary age, describing under this caption the fossiliferous deposits at Wailes Bluff. Desor, eight years later, described these same deposits and attributed the origin of the large boulders found therein to the transporting agency of ice.

Very little progress was made for the next 25 years. In 1877 Wm. B. Rogers published a paper on "Gravel and Cobblestone Deposits of Virginia and the Middle States." In this the author recognized clearly the origin of the surficial deposits in glacial times through the work of streams aided by the action of ice. He also made the important observation that these deposits were laid down at a time when the land was lower and the

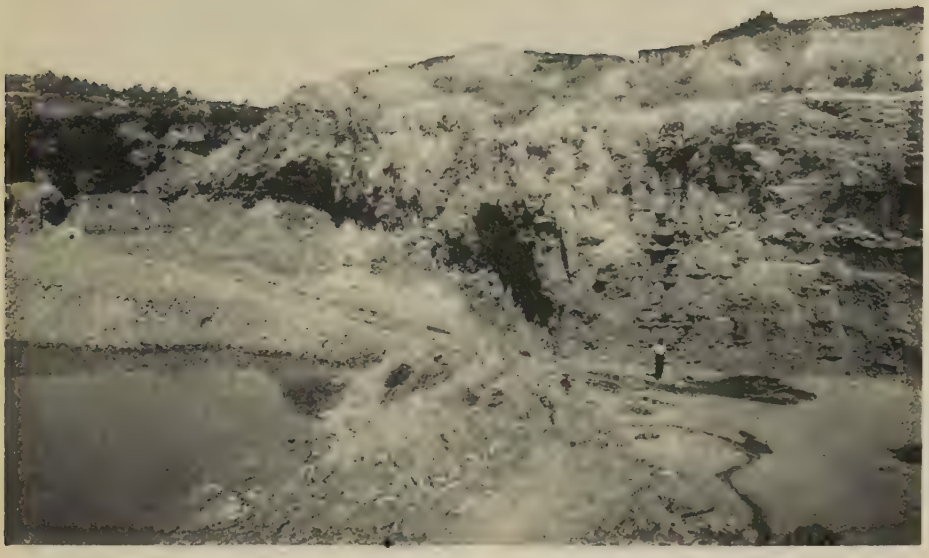

FIG. 1.—VIEW SHOWING REYNOLDS IRON MINE IN THE ARUNDEL FORMATION, 1 MILE SOUTH OF HANOVER.

FIG. 2.—VIEW SHOWING MASSIVE VARIEGATED CLAY OF THE PATAPSCO FORMATION, NEAR HAWKINS POINT.

headwaters of the present estuaries penetrated farther inland. He vaguely indicated the position of an old sea cliff near what is now designated the "fall line," which he made the source of many of the boulders occurring in the deposits. Chester, in 1884, working in Delaware and in eastern Maryland, also recognized an old shore line far inland from the present one and differing also from the "fall line." To these two men belongs the credit of recognizing to some extent the feature which enabled McGee, Darton, and Shattuck to work out a satisfactory classification of the surficial deposits by physiographic criteria.

The first worker, who, from the study of the surficial deposits, obtained a really philosophic grasp upon their stratigraphy, was W J McGee who, between the years 1886 and 1891, published several important papers on this subject.

In 1891 McGee, in an exhaustive memoir, discussed the Lafayette formation, since termed the Brandywine formation in the Maryland region. Three years previous he had recognized this as distinct from the later Pleistocene along the Middle Atlantic Slope and had designated it the "Appomattox" formation. In the later paper he asserted the identity of the Appomattox with the Lafayette as established by Hilgard in Mississippi in 1855 and 1856. McGee, though uncertain as to the exact age of these deposits, considers them "many times older than the earliest known Pleistocene deposits, and much newer than any other well defined formation of the coastal plain."

About this time Darton began his work on the surficial deposits, and during the next 10 years accumulated much data concerning them. He recognized an "Earlier" and a "Later" Columbia, and extended the northward limits of the Lafayette.

In 1901 Shattuck, working with improved topographic maps, recognized in the "Columbia Group" three distinct series of terraces, the Talbot, Wicomico, and Sunderland, with the Lafayette terrace at a still higher level. In 1906 he published an extensive monograph on "The Pliocene and Pleistocene Deposits of Maryland," in which the same classification—the one now employed by the Maryland Geological Survey—is retained.

The age of the Brandywine is not definitely determined and is left practically as stated by McGee.

A rather different classification of the New Jersey deposits has been developed by Salisbury. Shattuck, however, has stated that with the exception of the Brandywine, which is absent in that area, he has been able to apply his classification of the surficial deposits to the New Jersey area.

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THE PHYSIOGRAPHY OF ANNE ARUNDEL COUNTY

BY

HOMER P. LITTLE

Introductory

Maryland has been divided into three physiographic provinces—the Appalachian Region, the Piedmont Plateau, and the Coastal Plain; Anne Arundel County lying almost wholly within the last.

The term Coastal Plain is applied to the series of gravels, sands, and clays stretching along the Atlantic Coast from Martha's Vineyard to the Gulf. Throughout most of its extent the term also connotes the idea of deposits largely unconsolidated. Conspicuous through the middle district, at least of this coastal region, is a series of practically level plains, comprising the surficial deposits, each usually separated by a sharp offset from the one succeeding. No one driving across the country can fail to be struck by the fact that after passing across one level plain, then up a series of low choppy hills, or merely up one sharp rise, he often finds himself again on a perfectly level surface, but 15, 25, or perhaps 50 feet above the one he has just left. The geologist has found that these plains or terraces may be grouped together into a series of four members, or five if we include one now in process of formation, and he has given each a distinctive name. The lowest one—the one not yet complete—has been called the Tidal Marsh, or better, the Recent Stage; then come in order of increasing altitude and also of increasing age, the Talbot, the Wicomico, the Sunderland, and the Brandywine. The characteristics of each of these will now be discussed.

TOPOGRAPHIC DESCRIPTION

TOPOGRAPHIC FEATURES

Tide Marshes

Anne Arundel County is much freer from tidal marshes than are many regions of the Coastal Plain. Several of the larger rivers—the Magothy, Severn, and South River—have no marshes of large extent. There are three principal areas of tidal marshes; one, on the Patapsco River, is best developed near Brooklyn and extends to the head of tidewater; a second is found along the east margin of that area lying between Rockhole Creek and West River and known as "The Swamp"; the third and most considerable area is that along the tidal portion of the Patuxent River.

Since these marshes are partially submerged every day, and any little irregularities filled in by deposits of mud, it follows that they can show no permanent effects of erosion but will be practically flat and perfectly featureless. Theoretically, the higher terraces all possessed originally this same featureless character.

The Talbot Plain

The Talbot Plain is developed along much of the bay shore, and along the lower courses at least of nearly all the streams. The only considerable area of continuous development, however, is in the region between Rockhole Creek and South River, included in large part in the area above referred to as "The Swamp." Another typically developed area of Talbot, though not nearly so extensive as the preceding, occurs on the west shore of Curtis Creek along the main road to 1 mile west of Walnut Point. A third well-preserved fragment is found on the eastern extremity of the neck of land between Severn and Magothy rivers.

The Talbot Plain extends from sea level to about 45 feet above tide. It may be continuous with the tidal marshes below, or may be separated by a wave-cut cliff. The latter case is by far the more common. Since the Talbot Plain is the latest which has completely emerged above the sea, it has suffered but slightly from erosion. The county as a whole, however,

FIG. 1.—VIEW OF WHITE ROCKS, PATAPSCO RIVER, SHOWING SANDSTONE LEDGES OF RARITAN FORMATION.

FIG. 2.—VIEW OF GLASS SAND QUARRY IN RARITAN FORMATION, NEAR STONY POINT, SEVERN RIVER.

is so well drained that even this terrace has been generally cut into patches with the older deposits exposed between. This is clearly seen in the geological map of the region of the lower Patuxent, and of the various necks which jut out into the Patapsco. Even here, however, the valleys are so narrow and simple that in looking over the landscape these patches often present the appearance of an undissected plain.

The Wicomico Plain

This terrace is not nearly so well developed in the eastern section of the county as the Talbot. It is practically absent from the border of the large Talbot area of "The Swamp." There are areas of considerable development in the region between Benfield and Glenburnie, and in the vicinity of Woodwardville. It is, however, best and most typically developed in the western extremity of the county and in the southern half, along the Patuxent.

The Wicomico Plain lies at an elevation of from 40 to 100 feet above tide, and may in the upper courses of the larger streams reach 120 feet. It is usually separated from the Talbot Plain by a scarp of about 10 feet, similar to that separating the Talbot from the Recent. This may, as in the former case, be entirely lacking in places.

The Wicomico surface is more dissected than that of the Talbot below and much less dissected than that of the Sunderland above. A glance at the map in the region of the Patuxent just referred to shows how the minor tributaries have cut through it, and much more fragmentary areas are found farther inland.

The Sunderland Plain

The Sunderland Plain is typically and extensively developed throughout the southern half of Anne Arundel County (south of latitude 39°). North of here it has been largely removed, but the terraced surfaces found over large areas of the earlier formations bear witness to its presence until comparatively recent times. The only well developed Sunderland terrace of the northern part of the county is found extending from South

Baltimore to the region about Shipley and Linthicum. There are, however, numerous small patches scattered throughout the higher portions of the entire county.

The altitude of the terrace ranges all the way from 80 to 220 feet. It is almost invariably separated from the Wicomico Plain below by a pronounced scarp, often an exceedingly striking topographic feature. These scarps may be seen at almost any point in the southern part of the county, especially along the western border, but they are rarely typical in the northern part. One of the best of this latter section is to be seen a little over ½ mile south of Woodwardville where the scarp presents an abrupt rise of about 25 feet. Although the Wicomico below is well developed, the Sunderland has been largely removed, so that in all probability this scarp was formerly even more imposing than at present.

The Sunderland has been entirely removed over large areas, although the general configuration of the surface makes it certain that deposits representing this plain have been present. Even where it is preserved it often shows an undulating surface, and in the smaller remnants may be so cut up by secondary gullies and ravines that its original plain-like surface can be appreciated only by careful allowance for the modifying effects of stream erosion.

The Brandywine Plain

The Brandywine Plain has been almost entirely removed by erosion from Anne Arundel County. The only fragment left in the southern half of the county is at Marriott Hill. Another small remnant is found 2 miles east of Laurel, another 2 miles east of Jessups, and still another about 1 mile west of Stony Run Station. Outside of a few other insignificant exposures, this is the whole extent of the Brandywine in the region under discussion.

The Brandywine is found at altitudes ranging from 200 to about 300 feet. In more typical areas of development the Brandywine is separated from the Sunderland by a scarp similar to that separating the other plains. Only faint traces of such a scarp can be recognized in Anne Arundel County. This is what would naturally be expected for the

Sunderland sea submerged almost the entire county, and such exposures as are found apparently projected as small islands above this sea. The case of Marriott Hill is especially clear on this point, since it is surrounded on all sides by well developed deposits of Sunderland age.

The Brandywine sea is known to have cut a scarp in the solid rock of the Piedmont Plateau, but since Anne Arundel County was everywhere submerged during this period the development of the scarp was entirely to the westward of this county.

THE DRAINAGE OF ANNE ARUNDEL COUNTY

Stream Divides

Miller[1] has observed in the region just south of Anne Arundel County that the stream divides between Patuxent River and Chesapeake Bay lie much nearer the latter, and explains this by the fact that the bay has worn away the land on that side and has thus shortened the streams flowing into it. This is true only for the extreme southern part of the region under discussion—in that area around Herring Bay which marks the northern terminus of the Calvert Cliffs. The remainder of Anne Arundel County is pierced by large tidewater estuaries which penetrate far into the heart of the county. Their numerous and active tributaries have pushed the divides well over towards the Patuxent area. In comparison with the area to the south the seaward extension of these streams has been little shortened. The relief presented to the wave action is not so pronounced, and the slopes are often protected from erosion by low sandy shores which break the force of waves, and whose imponded streams indicate constructive rather than destructive work. There are some areas where very active erosion is taking place, as in the vicinity of Hawkins, Bodkin, and Thomas points, but the above statement is in general true, especially for the area between Severn and Magothy rivers, and between South River and Herring Bay. Both of these areas are composed largely of resistant Pleistocene clay, with level surface or sloping gently towards the bay. Although the interior of the county is well-drained and its surface cor-

[1] Patuxent Folio, No. 152, U. S. Geol. Survey, Atlas of the United States.

respondingly much dissected, nevertheless the narrow divides still preserve, especially south of latitude 39°, the flat terrace aspect so helpful in working out the past physiographic history of the region.

Tidewater Estuaries

Although many of the counties of Maryland are penetrated by larger tidewater estuaries, none can boast a series more strikingly beautiful than those of the Magothy, Severn, and South rivers. These streams are, indeed, commercially valuable and afford, especially in the case of the Magothy, transportation facilities by means of which many cargoes of choice fruit and vegetables find their way to the Baltimore market. They afford ideal locations for summer homes and recreation spots, and the opportunities they offer for these are being more and more appreciated. South River is as yet almost untouched, but landowners of the region are holding their property at fabulously high prices in expectance that future accessibility will bring their beautiful river into prominence. Magothy River is still the region of modest little cottages where those of moderate income may enjoy the advantages of life by the water. It is on the Severn that the greatest development has taken place during the last few years. From its mouth to its head the river is dotted with beautiful summer homes. As has been already mentioned, all these streams are largely free from marshes; they are lined throughout their course by high bluffs and are navigable by small launches to their very heads. Altogether they are ideal for the purpose for which they are being increasingly utilized.

Another series of estuaries, which are much smaller, take their value largely from their close proximity to Baltimore. These are Curtis, Rock, and Stony creeks. They are crowded throughout their length with little resorts much frequented in season.

Thus it will be seen that the estuaries have added much to the wealth of the county. Not only do they afford waterways, but they have made valuable large areas of land fronting on them, which in many cases would be almost valueless from an agricultural viewpoint.

The Patuxent River

The Patuxent River, including its tributary the Big Patuxent, forms the western border of Anne Arundel County from its southwest extremity to Laurel. The Patuxent River proper divides at Priest Bridge into two streams known as the Little and Big Patuxent. The total area drained is 960 square miles. The river is of little value to the county, for its availability for water power ceases at Laurel, while navigation begins only just before it leaves the county. Along much of its course in Anne Arundel County it is skirted by swamp land. It differs from the tide-water estuaries in that it presents two distinct stream types. First, there is that type ending at Laurel in which the river has a steep gradient, runs rapidly over a rock bottom covered with boulders, and furnishes considerable water power. This is the type of stream found to the west of the fall line. After passing into the Coastal Plain at Laurel the second type is presented. The river moves sluggishly over unconsolidated sediments, develops low banks which it overflows in time of high water, and in its lower course becomes estuarine in character.

The Patapsco River

The Patapsco River is similar in character to the Patuxent in that it presents in its upper course a rapid flow over a steep rocky bed, and in its lower course a slow movement over an area of gravels, sands, and clays. With its branch, Deep Run, it forms the north and northwest boundary of the county. Unlike Patuxent River, its navigable portion borders Anne Arundel County and aids greatly in putting the northeast portion of the county in touch with the Baltimore markets.

TOPOGRAPHIC HISTORY

Introductory

The surficial deposits described above—the Brandywine, Sunderland, Wicomico, and Talbot—are underlain by older sediments. These, however, have little to do with the topographic history of the county and will not be discussed. The sequence of events shown by a study of the surficial deposits—and their record is very clear—show that the sea formed each of these terraces in succession, carved out a scarp, and later retreated.

The Brandywine Stage

The Brandywine is preserved in only very fragmentary patches in Anne Arundel County. Wherever these are found, even at the extreme western border, they occupy the highest points. A terrace, then, reconstructed from these areas would overlie every other formation in the county; the sea which laid down these deposits covered the whole county just as the present sea covers all the deposits to the seaward of its wave-cut cliff; therefore the scarp of this period should be sought beyond the limits of the county where in fact it is found.

After the deposition of the Brandywine sediments the region was raised, eroded, some of the deposits just laid down were removed and in many cases it appears that the streams cut through into the underlying formations. The truth of this last statement is indicated by the fact that there are many exposures in each terrace where the débris removed by the waves from the opposing cliffs is composed entirely of material belonging to these lower formations. How far to the east the land extended at this and subsequent periods of elevation it is impossible to say. After erosion had proceeded for some time the land again began to sink and the next stage was ushered in.

The Sunderland Stage

As the land sank the sea once more flooded the county and gradually progressed inland, first flowing up the river valleys, later running more and more up the slopes, until finally almost the whole county was again inundated. As this sea worked its way landward it continually drove before it a wave-cut cliff which in a few cases was not pushed beyond the limits of the county. The two areas where this scarp is best preserved appear to have stood up from the Sunderland sea as islands, for they are surrounded on all sides by this sea cliff, with the older sedimentary formations exposed under the Brandywine cap. One of these areas is at Marriott Hill in the southern part of the county; the other is at the high hill 1 mile west of Severn Station. In both of these cases only a small patch of Brandywine is left, but the scarp is nevertheless strikingly clear.

At the latter locality, especially when viewed from the south, a most pronounced scarp is evident.

As in the preceding Brandywine stage, the Sunderland was brought to a close by an elevation which forced back the sea and exposed the surface of the land to the action of erosion. Some of the surficial deposits were removed, and doubtless parts of the underlying formations. Then once more subsidence occurred and the next stage began.

The Wicomico Stage

The Wicomico sea offers a marked contrast to the Sunderland in its areal extent over Anne Arundel County. While the Sunderland sea found its western limit almost wholly beyond the county, the Wicomico sea penetrated westward beyond its limits in only one instance. This exception was along the Patapsco, the ancient sea having found its way up the valley of the river to beyond Relay. This is proven by tracing and connecting the remnants of the old sea cliff which, as has already been pointed out, is so strikingly developed between the Sunderland and the Wicomico. This cliff may be taken as indicating a considerable period of stability at this stage.

The reference just above to the Wicomico sea having found its way up the ancient valley of the Patapsco River brings out an interesting fact—the larger rivers of this region have occupied their present valleys ever since the uplift which terminated Brandywine time. This may easily be seen, for fragments of every terrace after the Brandywine may be found lining the banks on either side, one above the other. This means that the streams of the Brandywine epoch cut valleys with sides so deep that neither the Sunderland nor any of the succeeding inundation could completely obliterate them, with the result that after each emergence they became again the natural lines of drainage to the sea. The rivers, cutting their way through the newly formed terraces, left on their borders the fragments visible to-day.

As in the preceding stage, the Wicomico was brought to a close by an elevation during which the phenomena of erosion of the preceding eleva-

tions were repeated. Then came the sinking which ushered in the last complete cycle.

The Talbot Stage

This stage differs but little from those preceding. A similar encroachment of the sea took place, although not to so pronounced a degree, and a similar sea cliff was gradually sculptured out along its margin. The lower courses of the streams were again partially filled with marine sediments and a considerable terrace was built up. This terrace, rather meagerly preserved in Anne Arundel County, may be seen in great development on the Eastern Shore, where entire counties are composed of it and have no other physiographic history.

The elevation which closed the Talbot is interesting in that it not only brought to the surface the present land area, but in addition a flat featureless plain which extended out into the bay some distance beyond the present shore line. Then, as in previous cases, was a submergence, present conditions were ushered in, and the county took on the general form which we know to-day.

The Recent Stage

As in previous stages, and probably at about the same rate, erosion is now at work tearing away the surface deposits and eating into the older deposits beneath. These are being transported by the rivers to the sea, where they are spread out over the bottom and help to build up the terrace now in process of construction. The streams have attacked the Talbot deposits only slightly because of its low elevation; the erosion of the waves in forming and driving inland the modern sea-cliff has been a more active agent in removing these latest deposits. But the older terraces, raised higher and higher by each retreat of the sea, are now at the highest elevation they have ever attained and are hence being somewhat more rapidly worn away. The entire disappearance of the Brandywine terrace from the county is indeed a matter of only a short time, geologically speaking. On the other hand, it is easy to imagine that a future uplift may add still another terrace to the list and inaugurate a new Recent Stage, but this is entirely within the realm of speculation.

THE GEOLOGY OF ANNE ARUNDEL COUNTY

BY

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Introductory

Anne Arundel County presents a nearly complete section of the Coastal Plain formations of Maryland. Two of these, the Arundel and the Magothy, find their type development within the county. The geological sequence is as follows:

Pleistocene Period.
- Sunderland Formation.
- Wicomico Formation.
- Talbot Formation.

Pliocene (?) Period.
- Brandywine Formation.

Miocene Period.
- Chesapeake Group.
  - Choptank Formation.
  - Calvert Formation.

Eocene Period.
- Pamunkey Group.
  - Nanjemoy Formation.
  - Aquia Formation.

Cretaceous Period.
- Upper Cretaceous Formations.
  - Monmouth Formation.
  - Matawan Formation.
  - Magothy Formation.
  - Raritan Formation.
- Lower Cretaceous Formations [Potomac Group].
  - Patapsco Formation.
  - Arundel Formation.
  - Patuxent Formation.

No continuous section exposing all these formations one above the other is known, but it is confidently believed that to the seaward, where erosion

has had no chance to work, each occurs above the other in an unbroken sequence.

Although these formations, outside of the surficial deposits, are all distinguishable paleontologically and most of them lithologically, there are certain features which they possess in common. These are: (1) A strike approximately northeast and southwest. (2) A very gentle southeast dip gradually decreasing from about 90 feet per mile in the Patuxent formation to about 10 feet in the Choptank formation. (3) An increase of thickness down the dip. (4) A probable increase of dip as the old shore lines towards the Piedmont Plateau are reached, especially in the Potomac formations. (5) A prevailing unconsolidation of the deposits and consequent lack of folding and faulting. A common feature possessed by the surficial deposits is the predominance of original slope over dip. This is further explained under the discussion of the physiographic character of the Brandywine.

Although, as has been stated, the Coastal Plain forms practically the whole of Anne Arundel County, brief mention must be made of what is known as the Piedmont Plateau, since it penetrates the county at its western extremity along the bottom of the valley of Little and Big Patuxent rivers. The Piedmont Plateau is composed of very old crystalline rocks, which have been greatly metamorphosed in earth movements and subjected to many intrusions of igneous rock so that they contrast greatly with those of the Coastal Plain. Its principal interest here is that it furnished the greater part of the material which makes up the Potomac formations and that its seaward extension forms the base on which these rest. For further information, reference should be made to Volume VI of the Maryland Geological Survey under the chapter on "The Physical Features of Maryland."

The characteristics of the various Coastal Plain formations will now be discussed in detail.

THE CRETACEOUS PERIOD

THE POTOMAC GROUP

The Potomac group is composed essentially of gravels and bright to somber-colored clays, in which those of bright color predominate. The three formations composing the group are quite similar lithologically, but the unconformities existing between each and the paleontological variations discovered have made it certain that in spite of any lithologic similarity very different ages are represented. Fossils are, however, by no means common, and the unconformities are often not evident, due to poor exposures or obliteration by similarity of material; the line of contact drawn may therefore at times be inexact, but even if the precise limits are not always represented the real relations of the beds are shown far more truthfully than by any system which grouped them together into one formation. The three formations are undoubtedly there—there are sections where they can be clearly pointed out—and if there is difficulty in determining the exact stratigraphic position of isolated exposures except by topographic position, this is a necessary difficulty in any classification which gives due consideration to the fact that more than one formation is represented in this series of largely unfossiliferous beds.

The Patuxent Formation

The term "Patuxent formation" is derived from the Patuxent River in the upper basin of which these deposits were first differentiated as an independent formation.[1]

Areal Distribution

The Patuxent formation is exposed only along the extreme northwestern edge of this region, where the Patuxent and Patapsco rivers with their tributaries have cut deep valleys and penetrated to the Patuxent beds. There are no outliers and the area of outcrop is continuous.

[1] Clark and Bibbins, Jour. Geol., vol. v, 1897, pp. 479-506.

Character of Materials

The Patuxent is prevailingly an arenaceous deposit, usually carrying a considerable amount of arkose, with local beds of gravel. At times large lenses of light to highly colored clays are developed which may resemble very greatly the variegated clays of the Patapsco formation. In the limited exposures of Anne Arundel County the arenaceous phase greatly predominates. The only good exposures occur at two large sand pits, one about 1 mile east, the other 1 mile northeast of Laurel. At the first of these, about 25 feet of arkosic sharp buff sand is exposed. White clay-balls are frequent, and at times the section is largely composed of argillaceous material in the form of white to yellow clay. Many thin fragments of iron crust brightly tinted by red hematite are present. These often form small geodes with very fragile walls. The material of the pit to the north of this one is much coarser, the sand tending towards a gravel and showing much cross bedding. The same tendency to grade into a whitish clay, especially in the lower part, is noticeable.

Paleontologic Character

The arenaceous character of the Patuxent has been unfavorable to the preservation of most types of life. The known fauna is limited to a Unio and the remains of a fish. The flora comprises the remains of ferns, cycads and conifers.

Although conditions were in general unfavorable for fossilization, there was one type of plant life for whose preservation these conditions seem to have been most favorable. This type was the trunk of the cycad. Large numbers of these were silicified, preserving the internal structure to some degree and the exterior form with much perfection. Although these trunks have been found lying on the surface of various formations above the Patuxent, there is a strong probability that they have been reworked and that the silicification of all these trunks took place in the Patuxent beds. They have nowhere been found in place, although what was probably the exact spot where one rested in the Patuxent beds was located. These trunks are interesting in showing the former abundance

of a now living but decadent type. A locality where several fragments of cycad trunks have been found, as well as a considerable amount of silicified wood of other families of trees, is on the farm of Noah Donaldson, 1 mile cross country east of Brock Bridge.

Strike, Dip, and Thickness

The strike of the Patuxent formation in this area is north-northeast by south-southwest, and the normal dip about 60 feet to the mile. Near the fall-line this increases perceptibly and there reaches 90 feet to the mile.

At many localities outside the county the Patuxent formation is considered to reach a thickness of 350 feet or more, while well borings point to a maximum thickness of nearly 500 feet. In Anne Arundel County the formation averages about 80 feet in thickness and probably does not exceed 100 feet.

Stratigraphic Relations

The Patuxent formation rests on crystalline rocks. These, as will be later shown, are a continuation and an integral part of the rock composing the Piedmont Plateau. The unconformity between these two represents a time interval compared to which any lapse found in the beds above is insignificant. In this county the Patuxent formation is almost universally overlain by unconformable beds of Arundel age.

The Arundel Formation

The term Arundel formation is derived from Anne Arundel County, where the deposits of this age are well developed. It was proposed by Clark and Bibbins[1] to include that series of clays lying between the Patuxent and Patapsco formations.

Areal Distribution

In distribution the Arundel is closely related to the Patuxent formation, occurring as a fringe, usually narrow, along its eastern edge. Like the Patuxent its exposure is due to the deep trench cut by the Patuxent

[1] Clark and Bibbins, Jour. Geol., vol. v, p. 485.

and Patapsco rivers and Deep Run near the western edge of the county; it never caps the divides, so that although of considerable thickness and well developed, its areal extent is comparatively small.

Good exposures of the Arundel formation are found opposite Hanover, Howard County; at the old mines, 1 mile southwest and $\frac{3}{8}$ of a mile south of Bridewell; and along the road, $\frac{1}{2}$ mile southeast of Annapolis Junction. Good exposures are numerous throughout the area of outcrop.

Character of Materials

The Arundel is essentially a clay formation carrying considerable quantities of iron ore. The presence of this latter makes possible most of the variations found in the otherwise rather uniform beds. When unweathered the clays are usually a dark blue-drab, containing numerous nodules or concretions of iron carbonate, often septarian in character. These are called "white" or "hone" ore by the miners. In the past this ore has been of much commercial value and is still mined to a limited extent. Masses many tons in weight have been found. A further discussion of these will be given under "Mineral Resources of the County." When weathered slightly the drab clay takes on a light pinkish-drab tone, which is very characteristic of mines or cuts where the surface has been exposed a comparatively short time. On continued exposure the carbonate alters to the hydrous oxide of limonite and the oxide hematite and the clays become a bright red, often greatly resembling the Patapsco clays above. The nodules then take on the form known to the miners as "brown" ore. The clays of the formation are very carbonaceous, and lignitic logs, much flattened, are common. Less frequently hematite and limonite have replaced the woody material, and large fragments of ferruginized logs are found, as at Reynold's iron mine. Occasionally trunks are found in an upright position with roots still in place.

Two very characteristic sections of this formation have been given in the original description of the formation.[1] They cannot be bettered and are given below:

[1] Clark and Bibbins, Jour. Geol., vol. v, pp. 487 and 480.

Section at Reynold's Mine, Piney Run, 1 mile south of Hanover.

Potomac Group.		Feet	Inches
Patapsco....	White and light brown sand and gravel, containing crusts of iron-stone[1]	10	
	White variegated argillaceous sands, "fuller's earth," clay and paint clay with paint rock at the base. Silicified coniferous and cycadean trunks	10	
	Ferruginous ledge more or less conglomeritic		3
Arundel....	Drab-colored compact laminated clays, containing beds of lignite and bearing fern impressions; nodules, flakes and ledges of "white ore" slightly plant-bearing	70	
	Total thickness	90	3

Section at Timberneck on Licking Run, 1 mile southwest of Hanover[2]

Potomac Group.		Feet
Patapsco....	Reddish sands, somewhat gravelly, containing "pipe ore"[3]	12
	White, red, and brown sands, more or less argillaceous, containing clay pellets	20
Arundel....	Drab-colored pyritous clays with beds of lignite; pellets, nodules, and flakes of carbonate of Iron ("white ore")	100
	White clay (in bed of Licking Run)	5
	Total thickness	137

Paleontological Character

The Arundel, though not abundantly fossiliferous, contains both plant and animal remains. These latter have played an important part in the controversies which have arisen as to the age of the Potomac group, for they include those dinosaur remains collected from the Muirkirk area in the neighboring county of Prince George's on which most of the arguments in favor of the Jurassic age of the lower Potomac beds have been based. Of the several localities in Anne Arundel County in which fossil leaves have been found the only one of any importance is Soper Hall, a

[1] Considered Raritan in original report.
[2] This section occurs just over the line in Howard County.
[3] Considered Raritan in original report.

region of abandoned iron mines, about 2 miles below Elkridge Landing on the right bank of the Patapsco, where *Sequoia ambigua* Heer and *Sphenolepsis sternbergiana* Schenk have been collected. At this same locality a few teeth and bones, probably belonging to dinosaurs, have been found.

Strike, Dip, and Thickness

The strike of the Arundel formation is about north-northeast and south-southwest as in the preceding formation. The dip is slightly less than that of the Patuxent, being 40-50 feet to the mile. Like the Patuxent, its dip increases towards the fall-line where it reaches about 72 feet to the mile.

The thickness of the formation in Anne Arundel County cannot be exactly stated. As seen in the section at Licking Run, it reaches at least 100 feet. The maximum for the county is probably about 125 feet.

Stratigraphic Relations

The Arundel formation overlies unconformably the Patuxent and is in turn overlain unconformably by the Patapsco.

The Patapsco Formation

The term Patapsco formation[1] is derived from Patapsco River, along whose lower course beds of this age are well developed.

Areal Distribution

The Patapsco formation is widely exposed throughout the northern half of Anne Arundel County. It dips below sea level to the east of the line of strike, passing south-southeast from Stony Creek. At first it is exposed only in the bottom of the stream valleys, but unlike the preceding formations it quickly rises to the surface and caps the divides over large areas. Very good exposures are found at Hawkins Point, the type locality; at Marley Station, on the Annapolis Short Line, and throughout Marley Neck; at the sand pits overlooking South Baltimore; and in the

[1] Clark and Bibbins, Jour. Geol., vol. v, p. 489, 1897.

FIG. 1.—VIEW OF THE MAGOTHY FORMATION AT CAPE SABLE (NORTH FERRY POINT), MAGOTHY RIVER.

FIG. 2.—VIEW SHOWING THE MATAWAN FORMATION OVERLYING THE MAGOTHY FORMATION AT ROUND BAY, SEVERN RIVER.

western part of the county in almost any of the numerous cuttings where the roads descend into the deep stream valleys of the region.

Character of Materials

The Patapsco is a formation of very variable lithologic character in both vertical and horizontal directions. Sands grade into clays and vice versa with remarkable frequency. The great variability of the formation may be realized from the fact that a well digger reported to the writer that he found at one house, after passing through a thin covering of sand, about 40 feet of tough variegated clay, while at another house almost directly across the road and at approximately the same level he passed through 40 feet of sand without a trace of clay. Taken as a whole, however, the argillaceous materials largely predominate, and although cocoa-colored, dark-drab, or light-colored clays may be developed, the Patapsco is essentially a formation of brightly colored variegated clays, strikingly mottled with shades of red, purple, and gray. Local beds of gravel may occur, occasionally cemented to form a conglomerate, as at the contact with the Arundel near Reynold's iron mines, on Licking Run. The arenaceous phase is usually represented by a clean, sharp, light buff sand, strongly contrasted with the much iron-stained clay. In the vicinity of the clay the sand is often indurated. This may form what is known as "pipe ore" or may occur merely as thin ledges of a brown friable sandstone. At times this sandstone forms large masses of resistant rock. The sands are often very uniform and free from gravels, as in the pits overlooking South Baltimore. Near the base of the formation occurs a clay exceedingly rich in ocherous hematite, known as "paint rock."

Section at northernmost of Rayner's sand pits, South Baltimore

		Feet
Pleistocene.		
Sunderland	Iron-stained conglomerate, strongly cemented, containing coarse and fine gravels	3
Potomac.		
Patapsco	Harsh light-buff sand, very homogeneous throughout	29
	Total thickness	32

Section 1 mile south of Hawkins Point

		Feet	Inches
Pleistocene.			
Talbot	Chocolate-drab sandy to very argillaceous loam, compact, with a few small well-rounded pebbles at the base	6	
Potomac.			
Patapsco	Fine harsh sand, irregularly colored yellow, orange, buff, and white. Scattered throughout, but occurring especially at the base are flat iron crusts much broken, averaging about 1 inch thick	4	6
	Variegated purple, pink, red, and gray massive clays	20±	
	Total thickness	30	6

Paleontologic Character

In general, the fossils of the Patapsco formation consist of plant remains representing ferns, cycads, conifers, monocotyledons and dicotyledons. Several dicotyledons are of very primitive type. A few poorly preserved molluscan forms have been found. Anne Arundel County has contributed nothing of importance to the flora. One plant-bearing locality was discovered ¾ of a mile north of Woodwardville and ¼ of a mile west of the railroad crossing, where specifically unidentifiable cycad leaves and fragments of dicotyledons were found. The material in which they occurred was a sandy cocoa-colored to drab clay lens near the base of a thick exposure of variegated clay. A few fragments of dicotyledonous leaves were found in the blue pottery clay exposed in the cliff on the estate of Frank Hancock 1½ miles south of Hawkins Point. Leaves have also been found in a drab clay in "Kelly's Cut" on the Annapolis Short Line, just north of Wellhams. These were identified by Berry and all found to be characteristic Patapsco forms. They are:

Acrostichopteris longipennis Font.
Celastrophyllum parvifolium (Font.) Berry
Cissites parvifolius (Font.) Berry ?
Nageiopsis angustifolia Font.
Nageiopsis zamioides Font. ?
Onychiopsis psilotoides (S. and W.) Ward
Pinus vernonensis Ward
Populophyllum minutum Ward
Populophyllum reniforme Font. ?
Widdringtonites ramosus (Font.) Berry

Strike, Dip, and Thickness

The strike of the Patapsco formation is like that of those preceding, approximately north-northeast and south-southwest. The dip is slightly less—35-40 feet per mile—increasing in the vicinity of the fall-line.

The thickness of the beds in Anne Arundel County is about 200 feet.

Stratigraphic Relations

In this county the Patapsco rests on the Arundel formation, which it overlies unconformably. In areas where the Arundel was not deposited it rests directly on the Patuxent, or overlapping even this, may rest directly on the crystalline rocks of the Piedmont Plateau. This unconformity at the base of the Patapsco is very marked. The unconformity at the summit, on the other hand, is not easy to detect, and where the sandy phase of Raritan and Patapsco are coincident differentiation may be well nigh impossible.

THE UPPER CRETACEOUS FORMATIONS

The Upper Cretaceous formations are well developed in Anne Arundel County. Each is separated from the succeeding formation by an unconformity.

The materials composing the Upper Cretaceous beds are very variable, and were it not for paleontological evidence it is certain that they would never have been grouped together. The lower beds represent a continuation of the conditions of the Potomac group, while the upper members—the Matawan and Monmouth—represent strictly marine conditions. Fossils, though not so numerous as in the later epochs, are far more common than in the Potomac group and are found in an identifiable condition in every formation except the Monmouth.

The Raritan Formation

The Raritan formation receives its name[1] from Raritan River, New Jersey, along whose course the deposits are typically developed.

[1] Clark, W. B., Ann. Rept. State Geologist N. J. for 1892, pp. 181-186, 1893.

Areal Distribution

The Raritan formation is widely exposed in Anne Arundel County west of the line of strike which passes southwest from 2 miles below Bodkin Point. It continually rises higher and higher, and the width of the outcrop widens until in the region about Odenton it occupies much of the surface of the country. From here west the land rises at about the same rate as the formation, so that exposures are found on the divides well towards the edge of the county, giving the Raritan a large areal extent.

By far the most satisfactory and characteristic sections are found on Severn River, especially at the pits of the Brennan Sand Company, ½ mile below Forked Creek.

Character of Materials

The Raritan formation, because of its similarity of origin, more closely resembles lithologically the Lower than the Upper Cretaceous. Like the formations of the Potomac group, its strata vary rapidly in character both horizontally and vertically; sands pass into clays, and these in turn pass back into sands with startling rapidity. The clays are often pink in color and occasionally dark red, but this latter is looked upon as an exception. Drab, chocolate, and slate colored clays are also found. Along the Severn River white clays, sometimes stained yellowish by limonite, predominate. A pure white clay may pass horizontally within a few feet to one of a pronounced red color, or it may pass into a pure white sand. Some of the drab and chocolate clays contain leaf impressions, but the red and pink clays are apparently barren. These latter often contain pockets of dark red ocherous hematite known as "paint pots." This type of hematite deposit is very seldom found in continuous beds such as occur in the Patapsco.

The sands of the Raritan are medium to coarse grained and angular, and predominatingly buff in color. As in the case of the clays, however, there is an unusual development of a pure white phase on the Severn River. It was this which suggested to Uhler the term Albirupean, a name which

in this area is nearly coincident with Raritan. These sands are by no means confined to the Severn, but are most typically and extensively developed there. They are often consolidated by a siliceous cement into an exceedingly hard sandstone which has been to some extent used for building purposes. It often stands out in the form of great isolated boulders. A group of such boulders located ½ mile east of Elvaton is one of the most striking examples of consolidated rock in the Coastal Plain of Maryland. A brown, compact sandstone cemented by iron also occurs. This often contains many small angular fragments of quartz which are quite characteristic, appearing much as though shattered by the blow of a hammer and then scattered at random through the sandy material.

Besides clay and sand, gravel is often found consisting of clean subangular quartz or quartzite pebbles. Occasionally these are cemented by iron into conglomerates. Although the gravel as a rule appears to occur disseminated throughout the material of the formation rather than as distinct gravel bands, it may become concentrated at the surface as a continuous sheet due to the selective agency of erosion. This gravel then becomes extremely troublesome to separate from the surficial deposits of the Pleistocene, and no criterion to cover all cases can be found. The frequent thinness of these deposits, which occur usually only as a veneer, their cleanness, their rather uniform character, and their general freedom from débris of igneous rocks, are of assistance, and any or all of these taken in conjunction with the topography and stratigraphic relations will serve as a rule to differentiate the formations with considerable certainty.

Of the subordinate constituents of the Raritan formation, pyrite and lignite are the chief. These two are found in great abundance at the base of the low Raritan cliffs just south of Bodkin Point. Here the pyrite has filled in cavities in the decayed wood and partially replaced it. Very handsome specimens of the two may be obtained here. Large lignitized trunks, much flattened, also occur. Amber in small quantities has been found in the drab clays on the Severn River.

Numerous good sections are exposed along the Severn River; otherwise they are not common. The most complete section was obtained at the Brennan Sand Company's pit. This, with others, is given below:

Composite section at Brennan Sand Company's pit, Severn River

		Feet	Inches
Upper Cretaceous.			
Magothy....	Small pebbles (⅛ inch) cemented with sand...	2	
	Coarse sand	1	6
Raritan.....	Brick-red and gray mottled clay	16	
	Tough, plastic, greenish-black clay	5	
	Red, hematitic clay, lithified, slightly sandy...		1
	Light snuff-colored, plastic clay, lower 2 feet showing alternating bands of pink and snuff, varying horizontally to a pure white pottery clay	6	
	White sand	3	
	Light gray clay, with knife edges of white sand	3	
	White glass sand, medium coarse, with some arkose	10	
	These last two members have been shown by borings to continue downwards for 77 feet, the upper 30 feet of this being glass sand.		
	Total thickness	45	7

Section ½ mile below Forked Creek, Severn River

Upper Cretaceous.		
Raritan.....	Loose yellow sand and white compact sand, alternating	10
	White massive cross-bedded sand	10

The proportions of these two is very variable. At the highest point of the cliff the section is as follows:

		Feet
Raritan.....	Very plastic grayish-white clay, with occasional patches of bright red clay	10
	Massive white sand	12

Section at Clark's sand pit, 1 mile south of Severn Station

Upper Cretaceous.		
Raritan.....	Cross-bedded buff sands with occasional balls or thin lenses of grayish clay	25

Paleontologic Character

In various localities outside of Anne Arundel County the Raritan contains abundant and well preserved plant remains, dicotyledons predominating. These occur usually in drab clay, never in the pink or red. Occasionally leaves are found in slabs of very hematitic sandstone. Within the county under discussion fossils are very rare, and identifiable species

are known from only two localities. E. W. Berry has furnished the following memorandum which constitutes the flora so far as known.

I. Riverside Brick Company, Severn River (present site of Brennan Sand Company).
Aspidiophyllum trilobatum Lesq.
II. Severn Run, near Benfield.
Podozamites marginatus Heer
Sassafras cf. *acutilobum* Lesq.
Aralia sp.

No marine fauna is known in Anne Arundel County, nor have any vertebrate remains been found.

Strike, Dip, and Thickness

The strike of the Raritan formation is approximately northeast and southwest. The dip is 35 feet per mile, which is the greatest of any of the formations above the Potomac group. The thickness of the formation within the county is a little over 100 feet. This increases considerably down the dip.

Stratigraphic Relations

The Raritan formation is separated from the Patapsco by an unconformity which, however, may be very difficult of identification due to similarity of materials and to the very pronounced local unconformities occurring within both formations. The line between the Raritan and the Magothy formation is usually very clearly differentiated, although here also occasional similarities of material, especially of sands, may confuse the observer in an exposure of limited extent.

The Magothy Formation

The formational term "Magothy" was introduced by Darton[1] in 1893 for certain transitional deposits occurring above the Raritan and below the Matawan, especially well developed on the Magothy River. At first it was thought by some to represent merely a phase of the Raritan, but it has now been generally accepted as a term of coordinate value with Matawan, Monmouth, and the other Upper Cretaceous formations.

[1] Darton, N. H., Amer. Jour. Sci., 2d ser. vol. xiv, pp. 407-419, 1893.

Areal Distribution

The Magothy formation is well developed along the middle course of the Magothy River on its north bank, but is exposed only to a slight extent on the south side, due to the low character of the shore, which is covered by deposits of Talbot age. The deposits at Cape Sable on this river—or North Ferry Point, as the later maps designate it—have long been known in the literature, and many references to them appeared long before their place in the geologic column was even approximately known. The formation is equally well exposed on the Severn River in the region of Round Bay. Small exposures of typical Magothy, though isolated, are found on the bay shore a little over 1 mile below Bodkin Point, at the Forks of the Patuxent, on the Washington, Baltimore and Annapolis Electric Railroad, about 1 mile below Naval Academy Junction, and on the same line $\frac{1}{4}$ of a mile south of Conway Station. Various other areas have been mapped as Magothy, due to their position and relation to other beds which, considered lithologically alone, might with equal appropriateness have been placed in either the Raritan or the Pleistocene.

Character of Materials

The Magothy is a formation of varied lithologic character, comprising sands and clays and occasional conglomerates which change with considerable rapidity both horizontally and vertically. Where the clays predominate an exceedingly characteristic mode of occurrence is in the form of well developed laminae, which vary from little thicker than paper to an inch or more. The interspaces between the laminae are filled with white mica and fine white sugary sand spread over the clay surface as a thin film about the thickness of one of the grains of sand. The clays themselves may be black or light chocolate drab with all intermediate stages, and are free from mica.

The sands where more largely developed may be fine and sugary, medium grained, or very coarse. The first and last of these types when present will usually serve to differentiate the formation. The fine snow-white sugary sand, often with fine particles of white mica, occurs in little pockets and often serves to give a clue to the presence of the formation

when all other means of identification are lacking. It is rarely that any other formation of the county shows this type of material. The coarse sand also is very characteristic. This sand occurs in translucent to transparent grains about the size of BB shot, often showing an unusual proportion of blue or amethystine quartz. The sands, especially those of medium grain, are often loosely indurated and form a brown sandstone quite characteristic. On weathered or overgrown slopes this sandstone, projecting as a ledge, should serve to put the geologist on the lookout for other indications of the presence of the Magothy formation.

Lignite and pyrite are abundant, and in certain localities compose an essential part of the strata. At North Ferry Point the pyrite occurs in a compact ledge sufficient in amount to have been in the past commercially valuable. In the same section lignite is abundant and several varieties of amber have also been described from there. On the west bank of Valentine Creek, Severn River, are found very lignitic black clays. So far as known the Magothy of Anne Arundel County contains no glauconite.

Section at Laboratory Point, Cape Sable, Magothy River

		Feet	Inches
Matawan	Fine greenish glauconitic, yellow mottled sand. Sharp stratigraphic break at base	10	
Magothy	Loose and very coarse white sand interstratified with brown sand, containing small quartz pebbles, locally lignitic, indurated, and more or less cross-bedded	2	6
	Light blue clay (local)		2
	Fine white lignitic sand, with ferruginous crusts, locally indurated, friable	14	
	Black laminated clays interstratified with thin lamellae of white pyritiferous sand		6
	Compact yellow sand with amber	1	
	Lamellum of comminuted lignitized stems and leaves, crusts of pyrite, pellets of amber, alternating with black laminated clays		16
	Black, massive, earthy lignite, very compact, with rods, flakes, and ledges of pyrite and pyritized wood, becoming more pyritiferous towards base. Formerly utilized by the Troost Alum Works	4	
Raritan	Tough, blotched, pinkish clay underlain by white, very compact sand (at low tide)		5
	Total thickness	33	11

The following section illustrates some of the points brought out in the discussion of the "character of materials."

Section on west shore of Valentine Creek, Severn River

		Feet	Inches
Magothy	Black, laminated clay, breaking like shale, with much flattened lignitized stems. Many lumps of pyrite occur whose decomposition gives the whole shaly mass a sulphurous odor like that of a coal mine	6	8
	Coarse orange, yellow, and white sand, apparently capped by about 1 foot of iron conglomerate	11	
	Total thickness	17	8

Section at Little Round Bay, Severn River, ⅞ of a mile west of Long Point

		Feet	Inches
Magothy	Light chocolate-drab sandy clay, very compact, with many small pebbles towards the base. Leaf fragments in the more argillaceous portions	12	
	Iron crusts		½
	Very coarse angular quartz sand, grains averaging almost ⅛ of an inch in diameter; a large proportion of blue and amethystine grains	2	
	Unexposed	10	
	Total thickness	24	½

Section ⅞ of a mile northwest of North Ferry Point, Magothy River

Upper Cretaceous.			
Magothy	Bright buff sand, lower 2 feet quite coarse, sometimes indurated	6	
	Black lignitic clay, alumiferous water. Marked undulating unconformity at the base	8	
Raritan	White clay ("fuller's earth") grading downwards into next member	4	
	Red clay	2	
	Total thickness	20	

Paleontologic Character

Although invertebrates have been found in the Magothy formation to the north, especially in New Jersey, the only organic remains known from

this formation in Anne Arundel County are those of plants. Amber is quite common. In Upper Cretaceous deposits to the north this is known to have been secreted by a species of pine. Lignitized stems of trees are common. At certain localities quite perfect leaf impressions are found. The following list of plants from the chocolate-drab clays at Round Bay has been identified by Berry:[1]

Andromeda Cookii Berry
Andromeda Novæ-Cæsareæ Hollick
Andromeda parlatorii Heer
Cinnamomum Newberryi Berry
Eucalyptus Geinitzi (Heer) Heer
Eucalyptus latifolia Hollick
Sabalites magothiensis Berry
Laurophyllum elegans Hollick
Laurus plutonia Heer
Laurus proteæfolia Lesq.
Moriconia americana Berry
Nelumbo primæva Berry
Quercus morrisoniana Lesq.
Quercus severnensis Berry
Rhamnites apiculatus Lesq.
Sequoia ambigua Heer
Sequoia Reichenbachii (Gein.) Heer
Widdringtonites Reichii (Ettings.) Heer

Strike, Dip, and Thickness

Very good opportunity for observing the strike of the Magothy formation is offered at Round Bay on Severn River. The points at which the Magothy dips beneath the water on each bank are accurately known and the distance between these points—2 miles—is sufficient to give a good measurement. The result found is a strike of N. 44° E. The strike varies farther north, swinging more to the east on the Magothy River.

The dip of the formation is about 30 feet to the mile. On the Severn the distance of its exposure along the dip is about 1 mile, giving a thickness there of 30 feet. This increases rapidly towards the Magothy River, where it is about twice as much. This fact may be sufficient to explain the increased eastward trend of the strike just referred to.

[1] Berry, E. W., Bull. Torrey Botanical Club, vol. xxxvii, pp. 10-29, 1910.

Stratigraphic Relations

The Magothy is separated from the Raritan by one of the most conspicuous unconformities of the Coastal Plain. The Magothy, however, often contains sands identical in appearance with sands occurring in the Raritan and this, combined with the fact that both formations show numerous local unconformities, may make it very difficult to draw the line between them. But whenever the Magothy dark laminated clays rest upon the irregular white or pink clay surface of the Raritan, the unconformity is striking. Such a section, $\frac{7}{8}$ of a mile northwest of North Ferry Point on the Magothy River, has already been given. Sections of the first type are found just east of Cedar Point.

A less marked unconformity separates the Magothy from the Matawan above, but there usually is little trouble in drawing the line between the two, due to the practical absence of glauconite and mica in the Magothy of this county and the presence of both in the Matawan.

The Matawan Formation

The term Matawan formation[1] is derived from Matawan Creek, a tributary of Raritan Bay, New Jersey, near which characteristic deposits of this age are well developed.

Areal Distribution

The Matawan formation is typically developed along the lower courses of Magothy and Severn rivers. It is also found in force in that area bounded roughly by Gotts, Crownsville, Chesterfield, St. Stephen's Church, and Millersville. In the more eastern part of this section the exposures are found near the heads of the deep ravines which enter the main streams. Farther west they rise to the surface and cap the hills. One of the most accessible exposures, also a fossiliferous one and very typical, is found in the railroad cutting $\frac{3}{4}$ of a mile southeast of Millersville Station.

[1] Clark, W. B., Jour. Geol., vol. ii, pp. 163-164, 1894.

Character of Materials

The Matawan contrasts greatly with the preceding formation in that it is, when unweathered, very uniform in character. It consists from top to bottom of a black sandy clay, with mica and glauconite. These last vary in abundance, but are seldom absent. The glauconite may be disseminated throughout, or may be somewhat localized in pockets. This latter case, however, is usually noticed after weathering has affected the beds.

When affected by weathering various changes take place, usually producing a gradual change from the typical greenish-black of the formation to a mealy-buff sandy clay. This latter is sometimes indurated, but not so frequently as are the more glauconitic formations above. A very instructive section showing on a small scale various stages in weathering was found in a pit beside the railroad tracks at Round Bay Station. This section is as follows:

Section at Round Bay Station

		Feet	Inches
Matawan	Dark buff, argillaceous, sandy loam, grading into member below		15
	Light brown sandy clay, somewhat glauconitic, grading into member below	2	
	Green sandy, micaceous, glauconitic clay, grading into member below		15
	The same, with ill-defined pockets of chocolate-drab clay and irregular streaks of red-brown argillaceous sand, with considerable glauconite, grading into member below	1	6
	Chocolate-drab sandy clay with red glauconite, grading into member below	4	
	Black laminated clay, with sulphur-colored streaks, glauconitic, slightly micaceous	2	
	Limonitic iron crust		1
Magothy	Chocolate, yellow, and orange sand		6
	Very light buff, fluffy sand, drying to a gray, with small decayed lignitic fragments and small pockets of chocolate argillaceous sand, exposed	2	
	Total thickness	14	4

When exposed on the surface for some time the glauconite may largely disappear, the clay may largely wash away, and only a fine buff sand be

left, difficult to differentiate. As a whole, however, the characters of the formation are very persistent, and even after extended weathering present certain well defined characteristics, appearing either as a sandy clay mottled green and yellow or merely orange-yellow, or as a shaly light cocoa-colored sandy clay in which careful search often reveals pelecypods, gastropods, and cephalopods.

In addition to the above-mentioned features the Matawan shows quite commonly large log-like or oval concretions of clay ironstone, also very characteristic. They weather in concentric layers and often persist after all other characteristics of the formation have disappeared. Since no similar concretions are known in other Upper Cretaceous formations of the county, they are often of great aid in identifying problematic exposures. A few localities where these concretions may be found are: On the south side of Dutch Ship Island, Magothy River, near the top of the 20-foot cliff where there are some roughly oval concretions about 2 feet by 2 by 1. These are in fresh material. A series in much-weathered and otherwise indefinite material occurs in a shallow cutting in the main road just 1½ miles west of Long Point, Severn River. Another locality, and one where they, as well as the rest of the formation are superbly developed, is in the deep ravine near the house of Mr. Carr, 1¼ miles southwest of Crownsville.

Lignite and pyrite are also found in the Matawan, and much less frequently, fragments of amber.

Section 2/10 of a mile east of wharf, Round Bay, Severn River

Upper Cretaceous.		Feet	Inches
Matawan	Green sandy clay with brown and yellow sand	6	
	Chocolate-colored sandy clay, weathered on surface to buff and yellow, grading into member below	6	
	Black sandy glauconitic and micaceous clay, massive	12	
	Iron crust		2-3
Magothy	Very coarse sand, angular and cross-bedded, with considerable lignite	6	
	Total thickness	30	2-3

Paleontologic Character

The Matawan of Anne Arundel County is rather fossiliferous, but the material as a whole is poorly preserved and hard to obtain. No remains, outside of *Exogyra* and *Anomia,* retaining the shell have been found, and both of these were too decayed to show the surface markings satisfactorily. The shells have at times been imperfectly replaced by pyrite. Anthozoa, Echinodermata, Pelecypoda, Gastropoda, Cephalopoda, and Vertebrata are all represented. One of the forms best preserved and found at almost every locality where collections were made is *Veniella conradi* (Morton). Both valves often occur united and are very easily recognized. An interesting find was Teredo-bored wood ½ mile southwest of Ulmstead Point. The best localities found for collecting were at the point just mentioned, and at the base of the high cliff of Gibson Island, both on Magothy River; also ½ mile north of Arnold Point, Severn River, and at the railroad cut ¾ of a mile southeast of Millersville.

Strike, Dip, and Thickness

The strike of the Matawan is approximately northeast and southwest. The dip is about 25 feet to the mile. The formation attains a thickness of 60 feet southwest of Crownsville. The average is probably a little less than 50 feet.

Stratigraphic Relations

The Matawan is unconformable with the Magothy below and with the Monmouth above. It is differentiated from the latter by the greater amount of argillaceous matter it contains, its lesser content of glauconite, and by its fossil content. Since, however, the Monmouth of Anne Arundel County is unfossiliferous, and since the transition from one formation to the other is gradual, it is not usually possible to designate the exact line of contact, although there is no difficulty in observing within a very few feet the passage from one formation to the other.

The Monmouth Formation

The name Monmouth as applied here is derived from Monmouth County, New Jersey, where deposits characteristic of this formation are well developed. The name was proposed by W. B. Clark[1] in 1897 for those deposits included in the Navesink and Red Bank formations.

Areal Distribution

The Monmouth is closely related to the Matawan in areal distribution. It is exposed along Severn River, and caps Gibson Island on the Magothy River. Especially good exposures of Monmouth, with the underlying Matawan, are found in the road cuttings where the road from Chesterfield descends to Bacon Ridge Branch on the east and Tarman's Branch on the west.

Character of Materials

As already pointed out, the Monmouth differs quite decidedly from the Matawan in the large decrease of argillaceous material and the decided increase of glauconite. The formation is then, as might be expected, looser textured than the Matawan except where it becomes indurated. The glauconite may at times be quite fresh and color the formation a dark green, but usually in the more accessible exposures it is either blackened by weathering, or has been largely dissolved and redeposited in irregular bands as a cement for the sand which becomes a rich red brown. These bands may form a complex anastomosing structure which, however, is developed to a greater extent in the Eocene. Numerous concretions, very characteristic of the Monmouth and much less so of the Eocene, occur. They are what from their general structure and appearance might be called "bomb" concretions; when not intergrown they are very nearly spherical and consist of an outer layer of loosely-cemented sand, stained yellow by limonite, grading gradually into a layer of compact, almost pure brownish limonite, the two being together about an inch thick. The whole forms a globular body varying much in size but averaging about

[1] Clark, Bull. Geol. Soc. Amer., vol. viii, pp. 315-358, 1897.

FIG. 1.—VIEW SHOWING CLIFFS OF DIATOMACEOUS EARTH OF THE CALVERT FORMATION AT FAIRHAVEN.

FIG. 2.—VIEW SHOWING THE CONTACT OF THE AQUIA AND NANJEMOY FORMATIONS IN VALLEY OF BEARD CREEK.

6 inches in diameter. This shell when broken open is found to contain comparatively fresh glauconitic sand, doubtless due to its preservation from the action of the weather by the dense protecting layer of limonite. These concretions occur in large number in a road cutting a little over ¾ of a mile east of Chesterfield.

The general appearance of an exposure of Monmouth in this county is as a bank of rather homogeneous sand more or less mottled red brown and gray. A rather generalized section, not all exposed in one vertical succession, is found in a road cutting just west of Waterbury Station, and is as follows:

		Feet
Miocene	Buff loose sand, overlying impure diatomaceous earth	6
Aquia	Brown argillaceous micaceous sandy loam, grading into member below	7
	Greensand, with a few small pebbles	2
	Greensand, mostly weathered a rich brown, often indurated especially towards base, carrying many casts of *Ostrea compressirostra*	3
Monmouth	Similar greensand, not so rich a brown, unfossiliferous	8±
Matawan	Mottled sandy clay with occasional poor fossil casts	5
	Total thickness	31

Paleontologic Character

No fossils have been found in the Monmouth within Anne Arundel County. In the adjoining county of Prince George's they are exceedingly abundant and at certain localities excellently preserved.

Strike, Dip, and Thickness

The strike of the Monmouth formation is approximately northeast and southwest, and the dip about 25 feet per mile towards the southeast. The thickness of the formation is variable, 50 feet is the maximum, and it thins to the northwest until near Waterbury it apparently is little over 10 feet.

Stratigraphic Relations

The Monmouth formation overlies the Matawan unconformably and is in this county overlain unconformably by the Eocene. As has been pointed out, the separation from the Matawan below is readily accomplished, but the drawing of the contact with the Eocene above is often attended with much uncertainty due to the great similarity of materials. This phase of the subject will be discussed more at length in considering the relations of the Eocene to the underlying beds.

THE EOCENE FORMATIONS

THE PAMUNKEY GROUP

The Aquia Formation

The Aquia formation receives its name from Aquia Creek, a stream emptying into the Potomac River on the Virginia side. The name was proposed by W. B. Clark[1] in 1895.

Areal Distribution

The Aquia formation is exposed over large areas in Anne Arundel County. It outcrops, usually in a weathered state, from 1 mile below the head of South River to its mouth. Perhaps the most striking exposure on the river is at the mouth of Broad Creek on the west bank. Other fine exposures are to be seen in the road cuttings near the Annapolis Waterworks, where the road descends abruptly to cross the headwaters of Broad Creek. But the most striking exposures of all are to be found in the high bluffs of the Severn, beginning opposite Annapolis and extending up the river for several miles. Here almost vertical cliffs rise in places to a height of 100 feet. On the higher levels of the neck between Magothy and Severn rivers is shown an almost continuous exposure of Aquia, terrace-like in form, due probably to the recent removal of the surficial deposits. Similar areas are found extending much of the way from Waterbury to several miles south of Crownsville. The Aquia also forms

[1] Clark, W. B., Johns Hopkins Univ. Circ., vol. xv, p. 3.

an almost continuous fringe along the Patuxent River from Governor Bridge to Hills Bridge. The most western exposure of Eocene, shown to be such by its fossils, is on the hill just east of Waterbury. An exposure still farther west, whose general relations indicate its Eocene age, is found on the high isolated hill 1 mile east of Conaways.

Character of Materials

The Aquia presents when unweathered, a rather uniform, massive bed of glauconitic sand, often slightly micaceous. The general color effect is either a light blue or dark green, almost black at times, dependent on the amount of glauconite. Physically the formation presents a rather dense compact mass, often eroding into steep-sided ravines.

In Anne Arundel County, however, this is not the typical manner of development. Here it has been subjected to more or less weathering, which either has altered the glauconite only slightly, merely rendering the beds less compact and coloring them brown, sometimes giving a mottled pepper and salt effect; in other cases much of the glauconite has been dissolved and then redeposited, forming layers of brown iron-cemented sandstone. At times a silica-cemented sandstone is formed which is so far as noted always fossiliferous. It occurs as a gray, hard sandstone flecked with grains of fresh glauconite. Characteristic developments are found in the vicinity of Crownsville, especially in the hills just to the east of the station. The brown sandstone may occur in the form of massive ledges, but a more characteristic type is found in the form of an intricate network of anastomosing or tubular crusts, enclosing masses of loose orange, yellow, or red-brown sands. Erosion wears away the loose sands and leaves the crusts projecting several inches from the cliff. This is a purely surficial phenomenon and bears no primary relation to the strata, but it is, nevertheless, a striking sight and makes a greater impression than the more important factor now to be mentioned, namely, the presence of considerable marl in the beds as contrasted to the Monmouth below. The marl is not conspicuous, but on close examination it will be seen in many places that the sands are full of fragments of carbonate of lime

which occasionally is sufficiently preserved to show that it is the product of disintegration of shells. These, however, have usually disappeared, and in the loose sands not even the casts remain, so that generally only a fine calcareous dust testifies to the former presence of an abundant molluscan fauna.

Paleontologic Character

Evidences are found almost everywhere that the beds of the Aquia formation have been in the past densely packed with the remains of an abundant molluscan life. Careful search will usually reveal either the casts of fossils or the witness of their former presence in the marly character of the materials. Even in banks of the most weathered sands casts are often found. It is, however, the exception to find the shells preserved. Some of the more accessible localities where the casts are plentiful are in the indurated sandstone at the mouth of Broad Creek, South River; in the high bluff opposite Horseshoe Point on the Severn; and in the road cutting opposite the entrance to Annapolis Water Works. In the road cutting just east of Waterbury is a ledge of brown sandstone containing many casts of *Ostrea compressirostra.* A very accessible locality is at the spur tracks of the Annapolis Short Line just across Dorsey's Creek from Annapolis, where many species may be found in the fragments of brown sandstone which lie scattered on the surface.

There are four species that are especially persistent at almost all localities and very easily recognized, so that it seems worth while to mention them by name. These are:

Dosiniopsis lenticularis (Rogers)
Glycymeris idoneus (Conrad)
Ostrea compressirostra Say
Venericardia planicosta var. *regia* Say

The recognition of any one of these species is very good evidence of the presence of Eocene strata. These, with all others most likely to be found, are figured and described in the Eocene volume of the Maryland Geological Survey.

Section on north bank of Severn River, 1 mile above railroad bridge

	Feet
Pleistocene.	
Sand and loam	5
Eocene.	
Aquia (Piscataway)..Coarse red, glauconitic sand, partially indurated, with *Ostrea compressirostra, Cucullæa gigantea, Meretrix ovata* var *pyga, Turritella mortoni*, etc.	20
Red glauconitic sand and talus	50
Total thickness	75

A similar section, but containing two fossiliferous layers separated by about 10 feet of barren glauconitic sand was observed by the writer ½ mile below the railroad bridge on the same side of the river.

The section[1] at the mouth of Broad Creek, South River, already referred to is as follows:

	Feet
Eocene.	
Aquia (Piscataway)..Ferruginous sandstone full of casts of *Turritella mortoni, Venericardia plancosta* var. *regia, Crassatelites alæformis*, etc.	10
Coarse oxidized greensand, with occasional casts of *Venericardia planicosta* var. *regia*	24
Talus	24
Total thickness	58

Strike, Dip, and Thickness

The strike of the Aquia formation is approximately northeast-southwest. The dip is slight, only about 12½ feet per mile to the southeast. The thickness is about 100 feet, though it apparently thins considerably towards the northwest, as shown in the region of Waterbury.

Stratigraphic Relations

In Anne Arundel County the Aquia is normally overlain conformably by the Nanjemoy. To the northwest, however, the Nanjemoy is either lacking or incapable of differentiation, and the Aquia is regarded as being

[1] Md. Geol. Survey, Eocene, p. 73.

overlain unconformably by the Miocene. The unconformity is plainly shown in the following section ½ mile south of where the road from the town of South River crosses Muddy Creek.

		Feet	Inches
Miocene.			
Calvert.....	Sandy loam and yellow and green, very fine sand Irregular contact, thin iron crust.	8	
Eocene.			
Aquia.....	Unusually black greensand with irregular streaks of sulphurous looking limonite.....	5	6
	Total thickness	13	6

A rather similar section may be seen in the road about ¼ of a mile south of Crownsville, where ash-colored diatomaceous earth rests upon glauconitic sand.

The formation rests unconformably throughout on the Monmouth. Whether or not this is true has been a disputed point, because of the occurrence opposite Annapolis of *Terebratula harlani* Morton. This species has been long regarded as a type fossil of the Rancocas—the Upper Cretaceous formation immediately overlying the Monmouth—and hence when this occurrence was discovered the Rancocas age of these beds was at once inferred. When, however, Bagg in 1898 found *Terebratula harlani* associated with Eocene fossils near Leeland[1] in the adjoining county of Prince George's, the occurrence of Rancocas strata on the Severn became a matter of uncertainty. Three explanations are possible—either Rancocas beds are present, though unattested, except by these isolated forms; or *Terebratula harlani* lived on into the Eocene, a possibility not inviting to those relying on it as a type fossil; or lastly, these forms have been mechanically derived from reworked Cretaceous sediments. With the idea of throwing some light on this problem, Mr. Berry and the writer visited the locality mentioned by Bagg and made a careful collection. A ledge with many perfectly preserved specimens of the *Terebratula* in question was found. The specimens are large, often attaining a height of 80 mm. and show the tendencies to variation mentioned by Schuchert[2]—

[1] Bagg, R. M. Jr., Amer. Geol., vol. xxii, p. 370.
[2] Schuchert, Chas., Md. Geol. Survey, Eocene, p. 204.

a tendency for the shell to become a little wider than the type with loss of lobation, and also to widen the area on each side of the crural processes. No indication whatever of reworking was found in the field, and all who have examined the specimens in the office agree that they are doubtless found in place. That they occur in undoubted Eocene strata the following list of intimately associated forms, identified by Mr. Berry, shows conclusively:

Meretrix subimpressa Conrad
Meretrix ovata var. *pyga* Conrad
Leda cliftonensis Clark and Martin
Dosiniopsis lenticularis (Rogers)
Lunatia marylandica Conrad
Crassatelites alæformis (Conrad)
Cucullæa gigantea Conrad (young and adults)
Turritella mortoni Conrad
Ostrea compressirostra Say
Venericardia planicosta var. *regia* Conrad (young forms)
Protocardia lenis Conrad

The conclusion reached, then, is that *Terebratula harlani* lived on into Eocene time, with the recognition of the fact that close study may make it necessary to create for the later form a varietal name.

This of course does not settle conclusively the age of the horizon opposite Annapolis, for there no associated Eocene fauna is found. However, it does make it possible to place these beds within the Eocene—where their position would doubtless naturally throw them—without the assumption that the contained forms are reworked. Furthermore, Bryozoans collected at a horizon approximately the same as that in which the *Terebratula* occurs and only a few yards away, are pronounced by R. S. Bassler to be of an Eocene type, though not specifically identifiable.

Subdivisions

Two members or substages have been recognized in the Aquia, the Piscataway below and the Paspotansa above. Each is characterized by its own group of fossils.

The Piscataway member receives its name from Piscataway Creek, which empties into the Potomac River on the Maryland side about 10

miles below Washington. It is characterized "by greensands and greensand marls, the lower beds often quite argillaceous. Two well marked and rather persistent layers of indurated marl characterize the upper beds in the Potomac region."[1] The member generally exceeds 50 feet in thickness and composes Zones 1-7 of the Maryland Eocene.

The Paspotansa member, so-called from Paspotansa Creek, which enters the Potomac River from the Virginia side, is composed of a thick bed of greensand overlain by thick-bedded indurated layers of greensand marl. It is generally somewhat under 50 feet in thickness and composes Zones 8 and 9 of the Maryland Eocene.

The Nanjemoy Formation

The Nanjemoy formation derives its name from Nanjemoy Creek, one of the Maryland tributaries of the Potomac River. The term was proposed by Clark and Martin[2] in 1901.

Areal Distribution

The areal distribution of the Nanjemoy formation is much more limited than of the Aquia. It is exposed in the stream beds along the Patuxent River from Lyons Creek to about 2 miles north of Hills Bridge, and extends as a disconnected band in a northeast direction to within about 1 mile of South River. Isolated exposures are found beyond the river in the hill 1 mile north of Beards Point and also at Thomas Point near the mouth of the river.

Character of Materials

The materials composing the Nanjemoy formation are in general similar to those of the Aquia, but they are more argillaceous, less marly, and at times quite gypseous. The argillaceous character is at times very prominent, especially at the base of the formation, where it may develop into a pure pink clay called the "Marlboro clay" from its type occurrence

[1] Md. Geol. Survey, Eocene, p. 60.
[2] Clark and Martin, Md. Geol. Survey, Eocene, p. 64.

at Upper Marlboro just beyond the Patuxent River in Prince George's County. Excellent exposures of this phase of the formation are found in Anne Arundel County, 2 miles east of Davidsonville, where the road crosses the headwaters of Beards Creek.

Section 2 miles east of Davidsonville[1]

Eocene.		Feet
Nanjemoy	Argillaceous, green-gray glauconitic sands, Marlboro pink clay	10-15
Aquia	Very fresh green-gray glauconitic sand uniform throughout	10-15

Paleontologic Character

The Nanjemoy formation is marked by a well-characterized fauna, though it is not so abundantly fossiliferous as the Aquia. Among some of the characteristic species are:

Leda improcera (Conrad)
Leda potomacensis Clark and Martin
Leda tysoni Clark and Martin
Lucina dartoni Clark
Lucina whitei Clark
Meretrix ovata var. *ovata* (Rogers)
Nucula potomacensis Clark and Martin
Ostrea sellæformis Clark
Venericardia potapacoensis Clark and Martin[1]

Fossils are found at various points along South and Patuxent rivers, but only in the form of casts.

Strike, Dip, and Thickness

The strike of the Nanjemoy formation is northeast by southwest, and the dip is about 20 feet to the mile. In this county the formation is not so thick as the Aquia, being about 60 feet as compared with 100 feet for the latter.

Stratigraphic Relations

The Nanjemoy rests conformably upon the Aquia and is overlain unconformably by the Calvert formation of the Miocene period. Although there is no unconformity between the Aquia and Nanjemoy, it is comparatively

[1] Md. Geol. Survey, Eocene, p. 64.

easy to locate their contact by the occurrence of the Marlboro pink clay at the base of the Nanjemoy formation.

It has already been stated that the Nanjemoy formation disappears, or at least becomes unidentifiable to the east, which brings the Miocene in direct contact with the Aquia.

Subdivisions

The Nanjemoy formation is divided into two members or substages, the Potapaco and the Woodstock. The former of these received its name from Port Tobacco Creek, Port Tobacco being a corruption of the old name Potapaco used on the early maps of the region. It is separated from the succeeding substage by its fossil content and includes Zones 10-15 of the Maryland Eocene. At the base of Zone 10 is found the characteristic Marlboro pink clay. The Woodstock substage is named from an old estate situated a short distance above Mathias Point on the Virginia side of the Potomac. It comprises Zones 16 and 17 of the Maryland Eocene.

For further details of the Nanjemoy formation, especially the paleontology, the reader is referred to the Eocene volume of the Maryland Geological Survey.

THE MIOCENE FORMATIONS

THE CHESAPEAKE GROUP

The term Chesapeake group is used to include that series of Miocene beds which is developed along the Middle Atlantic Slope. The group has been separated into three formations in Maryland, the Calvert, the Choptank, and the St. Mary's. Outside of one isolated exposure of the Choptank, only the basal of these formations occurs in Anne Arundel County.

The Calvert Formation

The term Calvert formation is derived from the typical development of beds of this age along the Calvert Cliffs in Calvert County. These outcrop almost continuously along the bay shore for a distance of about 30 miles.

and rising in a cliff almost 100 feet high, form perhaps the most striking exposure in the Coastal Plain of Maryland.

Areal Distribution

With the possible exception of the Aquia and the surficial deposits, the Calvert formation is the most widely exposed of any formation above the Potomac group. It is found at the head of almost every stream from the southernmost extremity of the county northward to a line connecting the Patuxent River with the head of South River. But few exposures isolated from the general area are found and these are small. One of the best occurs in the hill $\frac{1}{4}$ of a mile north of Iglehart Station; another is found in the hill 1 mile south of Crownsville, just west of the point where the road for Chesterfield branches off. A few other minor exposures occur in the same area. Numerous very good exposures are to be seen in the road cuttings in the more southern area of the county.

Character of Materials

The Calvert formation is composed essentially of diatomaceous earth, clays, and sands. At the very base is usually found a brownish to blue-green argillaceous sand. The diatomaceous earth—called fuller's earth locally—is of very persistent occurrence near the base of the formation. It is a greenish blue when fresh, but its surface exposure is almost invariably a very light ash gray. The amount of contained sand and clay varies greatly and the material may pass locally into a clay or an argillaceous sand. At other times the earth is quite pure. Just below it is often found a very marly ledge of sand, which may be indurated to form a compact layer of sandstone 6-8 inches thick. Above the diatomaceous earth there usually occurs a yellow to gray extremely fine sand. Nothing similar exists in any formation of the Coastal Plain outside the Miocene, except as reworked in the surficial deposits. It is very loose and the terms "fluffy" and "mealy," often employed as field characterizations, express accurately its appearance and constitution. This is especially true of the upper portion; towards the base it is quite argillaceous and passes by

gradual transition into the diatomaceous earth. A few characteristic sections are given below.

Section at Fairhaven, ½ mile south of wharf[1]

		Feet
Pleistocene.		
	Gravel, sand and clay	10
Miocene.		
Calvert	Diatomaceous sandy clay, bleached to a whitish color, jointed so as to have a rough columnar appearance, carrying *Phacoides contractus* (Zone 3 in part)	24
	Diatomaceous greenish sandy clay with conchoidal fracture, carrying *Phacoides contractus* and bearing rolled and reworked fossils from the Eocene in lower 2½ feet (Zone 3 in part)	36
	Total thickness	70

Section at Fairhaven, ⅛ of a mile north of lower wharf

		Feet
Pleistocene.		
Talbot	Yellow and gray sandy loam and sand (reworked Miocene) of varying thickness	6 ±
	Somewhat rounded pebbles, quite uniform in size, averaging ¼ to ½ inch, closely packed in matrix of buff sand	4
	Brownish-black peaty clay	8
	Knobbly appearing drab-green material, clearly reworked from member below	1-2
Miocene.		
Calvert	Bluish-green diatomaceous earth compact, covered at high tide, and extending out as a shelf at low tide, due to greater resistance to erosion (see pl. 18B). Exposed	2½
	Total thickness	21½ ±

Section at Iglehart, ¼ of a mile north of station

		Feet
Miocene.		
Calvert	Light fluffy sand, gray and buff, buff predominating, grading into member below	6 ±
	Diatomaceous earth, sometimes sandy, sometimes almost a clay, bearing occasional casts of pelecypods and impressions of fish scales, exposed	10
	Total thickness	16 ±

[1] Md. Geol. Survey, Miocene, p. 86.

Paleontologic Character

The Calvert is at places abundantly fossiliferous, though not so strikingly so in Anne Arundel County as farther south. The forms found in the diatomaceous earth are usually rather small. The most fossiliferous locality observed, and one where the forms were unusually large, was in the cut where the road for Nutwell branches from the main road. The best fossil locality found in the Calvert was near the point where the road crosses the little branch about ½ mile south of Pindell Station. Here the fossils occur as casts in an indurated sandstone ledge about 6 inches thick. Many genera are present, with Pectens especially abundant. These are often very large and are at times stained a rich red brown by limonite and sharply defined against the yellow-gray rock, thus making handsome specimens for collectors. No localities were observed where the shell substance is preserved. For a list of the fossils characteristic of this formation, and for figures and descriptions of those forms likely to be collected, reference should be made to the detailed report found in the Miocene volume of the Maryland Geological Survey.

Strike, Dip and Thickness

The strike of the Calvert is, like that of the preceding Coastal Plain formations, approximately northeast and southwest. The dip is to the southeast and only about 11 feet to the mile, which is somewhat less than that of the earlier formations.

The exact thickness of the Calvert is not known. Near Davidsonville it is only 50 feet thick, but the upper portion has been removed. A reliable well record at Crisfield, Somerset County, which passes through the entire Miocene series, shows the Calvert to be about 310 feet in thickness. Since all the formations of the Coastal Plain thicken down the dip quite rapidly, it can be said with assurance that the Calvert is much thinner than this in Anne Arundel County. B. L. Miller, however, has mapped it as over 100 feet in the stream bed about 1 mile south of Sudley, and even here the summit is not reached, for a cover of surficial deposits directly overlies it. The Calvert is, therefore, without doubt the thickest formation of the county above those comprising the Potomac group.

Stratigraphic Relations

In the southern part of the county the Calvert unconformably overlies the Nanjemoy, but farther north it rests apparently upon the Aquia. Near the Maryland-Delaware border it rests directly upon the Rancocas.

The Calvert is overlain unconformably by the Choptank formation when present. In this county the Calvert is almost universally directly covered by one of the Pleistocene terrace formations. It is seldom exposed except in stream valleys.

Subdivisions

The Calvert formation is subdivided into two members or substages, the Fairhaven diatomaceous earth below and the Plum Point marls above.

The Fairhaven diatomaceous earth receives its name from the village of Fairhaven, near the southern extremity of the county. This member, which is a little over 20 feet thick, comprises Zones 1-3 of the Maryland Miocene.

The Plum Point marls are named from Plum Point in Calvert County, and compose the remainder of the formation. They comprise Zones 4-15 of the Maryland Miocene.

The Choptank Formation

This formation will not be discussed in detail, since its only occurrence in this county is at an insignificant exposure scarcely mapable, visible in the scarp between the Brandywine and Sunderland at Marriott Hill.

The Choptank formation receives its name from its typical development on the north bank of the Choptank River near Dover Bridge. Although named from its occurrence on the Eastern Shore, it is in Calvert County that the best exposures are found. Its exact delimitation has been made difficult by frequent and extended coverings of the Columbia group.

The strike and dip are the same as in the Calvert formation, except that the dip is probably a little less, varying from almost horizontal to 10 feet

per mile. The greatest observed thickness is 50 feet. In the Crisfield well, however, there is apparently a thickness of 175 feet.

Lithologically, the formation is very variable. It includes fine yellow quartz sand, bluish-green sandy clay, slate-colored clay, and at times ledges of indurated rock. Abundant fossil remains are disseminated throughout. Although the Choptank has been shown to rest unconformably upon the Calvert formation, this is seen only through careful study and is not evident in ordinary observations, due to similarity of materials. The Choptank includes Zones 16-20 of the Maryland Miocene.

The St. Mary's Formation

The term St. Mary's formation is derived from St. Mary's County, where it is typically delevoped. The St. Mary's is entirely absent from Anne Arundel County. The best exposures in other areas are found along the bay shore, the Patuxent River, and St. Mary's River, in Calvert and St. Mary's counties.

The strike and dip are the same as in the preceding formation. In the well boring at Crisfield, already referred to, a thickness of 280 feet was found. This decreases up the rise until near Prince Frederick, Calvert County, the formation pinches out. In Maryland the St. Mary's is typically composed of a greenish-blue sandy clay, fossiliferous, resembling greatly the material of the Calvert formation. Locally the beds have been indurated by the deposition of iron; at times, also, clusters of radiating gypsum crystals are found. The St. Mary's lies unconformably on the Choptank formation, and is overlain by the various members of the Columbia group. Its subdivisions form Zones 21-24 of the Maryland Miocene and complete the section as developed in the state.

THE PLIOCENE (?) FORMATIONS

The Brandywine Formation

The term Brandywine formation is derived from Brandywine, Prince George's County, where the beds of this age are well developed. It was

proposed by Clark[1] in 1915, and has replaced the name "Lafayette," which had been applied to these deposits of the Atlantic Slope.

Areal Distribution

The Brandywine is, with the exception of the Choptank, the formation most poorly developed in Anne Arundel County. All told, its total extent in the county is only a few acres, and there are only three small areas where it can be said with certainty to occur. The first of these is at Marriott Hill in the southern part of the county, the second at the high hill 2 miles east of Jessups Station, and the third at the high hill ¾ of a mile west of Stony Run Station.

Character of Materials

It is not to be expected that in so limited an area of preservation a very general idea of the character of the materials could be obtained. Hence it is necessary to describe the characteristic development in areas outside of Anne Arundel. The best summary of this for the areas immediately adjoining this county is to be found in the Pliocene and Pleistocene Volume of the Maryland Geological Survey.

The materials composing the Brandywine formation consist of clay, loam, sand, gravel, and iron ore, which is present in the deposit as a cement, binding the loose material together in ledges of local development. These materials were imperfectly sorted by the waves of the Brandywine sea, so that they are now found intermingled in varying proportions. Although there is a rough bipartite division in the deposits as a whole, whereby the gravel occurs in greater abundance at the base, and the sand and loam at the top of the formation, yet these elements are mixed together in a confusing manner. Irregular beds or lenses of loam, sand, or gravel, are locally developed throughout the formation. Usually the Brandywine is capped by a deposit of loam varying from a few inches to 10 feet or more, and with an average thickness of about 5 feet. Along the Piedmont border this loam contains considerable iron and has a decided orange color, but in southern Maryland changes to a buff or yellow.

[1] Amer. Jour. Sci. (iv), vol. xl, 1915, p. 499.

FIG. 1.—VIEW SHOWING RECENT FILLING OF PATUXENT RIVER ABOVE LYONS CREEK.

FIG. 2.—VIEW SHOWING MODERN SEA CLIFF AND A PLEISTOCENE CYPRESS SWAMP IN THE TALBOT FORMATION, 1¼ MILES SOUTH OF BODKIN POINT.

Not a single clean-cut section is exposed in Anne Arundel County. In the hill west of Stony Run Station the surface of the hill is very gravelly, with a few boulders. The gravel are well rounded to subangular and quite coarse; they are as a rule quartzose, though occasional boulders of igneous rock are observed. The matrix appears to be a sand, colored brown by a large amount of iron-stained argillaceous material. In the exposure east of Jessups the upper member is well developed as a fine, brown, hard packing loam. At Marriott Hill the loamy phase is entirely lacking. The sand is coarse, loose, and almost white, resembling greatly a recent beach sand. The slope is gravel-covered, and the gravels for the most part only slightly rounded. They are as a rule rather small, although some larger ones up to 5 inches in greatest diameter were observed. Large fragments of ironstone conglomerate are numerous, and these and the gravel have doubtless acted together to protect the summit of the hill from degradation. The great freedom of the body of the mass from the coloring matter, so pronounced in most Brandywine strata, is the chief feature at this exposure.

Physiographic Expression

As has already been brought out at some length, the Brandywine represents the oldest and highest of a series of old sea floors successively developed along the Atlantic Coast. Their maximum westward extension was reached in Brandywine time, when the waves of the Atlantic beat directly against the cliffs of the Piedmont Plateau. As the sea retreated the sea floor rose as a terrace parallel to its original position. Therefore, as pointed out by Shattuck, true dip plays very little part in this formation, the dominant element being the original slope as determined by the sea bottom upon which the deposits were laid down. At present the Brandywine occurs at an elevation of 200-300 feet in various parts of the county, while in the most westerly exposures of the state it attains an altitude of about 500 feet. Little trace of the original terrace structure remains in Anne Arundel County, but at the three points described above there is little difficulty in identifying the deposits as Brandywine when they are considered both lithologically and physiographically.

Paleontologic Character

No fossils are known from the Brandywine of this region, and although in other areas plant and animal remains have been referred to the Brandywine, they have not been sufficiently definite to determine its age, the nearest key to which is found at present in its stratigraphic relations.

Thickness

The Brandywine, as a whole, probably does not average over 50 feet in thickness. At Marriott Hill this thickness is probably attained. At the two other localities cited it is somewhat less—30-40 feet.

Stratigraphic Relations

The very nature of the Brandywine—that of a surficial deposit formed by a sea gradually encroaching inland beyond the limits of previous inundations—leads to the natural supposition that it would be found resting unconformably on formations of various age, and this is indeed the case. In Anne Arundel County it is found resting upon the Miocene and Raritan only, although in the railroad cut just south of Naval Academy Junction it may possibly rest upon the Magothy. These relations throw a little light upon the age of the Brandywine, for, since it holds a position between the Miocene and the Sunderland, the formation may be considered as probably Pliocene in age. This conclusion, however, is not accepted by all, and the age of the Brandywine is still a matter of earnest discussion.

THE PLEISTOCENE FORMATIONS

THE COLUMBIA GROUP

The term Columbia formation was introduced by McGee[1] in 1886 from its typical development in the District of Columbia. Shattuck later raised this to a group term and recognized four divisions. These divisions are not characterized by forming paleontologic or lithologic units—they

[1] Report of the Health Officer of the District of Columbia for 1884-85, 1886, p. 20.

are too similar to be thus differentiated—but as pointed out by Shattuck, they do form pronounced topographic units in that each division consists of a well-defined terrace lying at a definite level and usually separated from the succeeding terrace by a scarp representing an ancient sea cliff. Viewed from this standpoint alone, the Brandywine would form one of these topographic units, but as already stated, certain other stratigraphic relations give evidence that this formation is considerably older. It is to be borne in mind, however, that some careful students feel that the Brandywine forms an integral part of the Pleistocene period.

The Sunderland Formation

The term Sunderland formation is derived from the village of Sunderland, Calvert County, near which it is typically developed. The name was first applied by G. B. Shattuck[1] in 1901.

Areal Distribution

South of parallel 39°, which runs just north of Annapolis, the Sunderland caps almost every divide. From here towards the north of the county it has been almost entirely removed, although a few patches have been left along the Big and Little Patuxent in the western part of the county. There is, in the extreme north, another extensive terrace of Sunderland age extending from South Baltimore westward almost to Stony Run, forming a comparatively level plain 6 miles long and averaging a little less than 1 mile in width.

Character of Materials

The Sunderland formation, like the Brandywine, is composed of loam, clays, sands, gravels, and occasional boulders, with no observable regularity of arrangement, except that the finer material tends to be at the top and the coarser at the bottom. In the exposure stretching westward from South Baltimore this is very uniformly the case, there being found at the base cross-bedded, ferruginous gravels with occasional larger boulders

[1] Shattuck, G. B., Johns Hopkins Univ. Circ., No. 152, May, 1901.

overlain by a fine brown loam some 10 feet in thickness. In the southern development homogeneous sands predominate, especially towards the Patuxent, and for miles scarcely any gravel can be found.

The origin of the larger boulders here and in the other terrace formations is attributed to the transporting power of blocks of ice which in Pleistocene time floated down the expanded streams and gradually dropped their load in this warmer climate. It is not to be expected that these boulders would be confined to any one horizon, and as a matter of fact they are not. Large fragments of rock often occur in the loam, with the complete absence of other coarse material which proves their origin by some transporting power other than water. These boulders are largely of igneous origin, although some large quartzite fragments occur. In the road cutting ¾ of a mile due east of Shipley, these boulders are unusually well developed at the contact with Patapsco white clay. Many of them are 1 to 2 feet in diameter. Although the gabbro blocks average much the larger, one quartzite boulder was observed 4½ feet in greatest diameter. The gravel phase of the Sunderland may be seen to great advantage in the various pits overlooking South Baltimore just opposite the car works.

Physiographic Expression

The Sunderland forms the plain lying at the level immediately below that of the Brandywine, from which it is separated by a scarp. This scarp, owing to the poor development of the Brandywine within the county, is rarely seen. It is found, however, fairly well developed at the three exposures of Brandywine already referred to, namely, Marriott Hill, 1 mile west of Stony Run Station, and 2 miles east of Jessups Station. Throughout the Coastal Plain the Sunderland is also separated from the Wicomico below by a well-developed scarp.

Because of its height above tide and its greater age relative to the lower lying terraces, the Sunderland has been as a rule changed from a flat surface to a rather rolling plain, at times much dissected. Where stream erosion has been most active the deposits may be entirely removed. Occasionally when none of its deposits remain *in situ* its former presence

is evidenced by the topography and by boulders too heavy to be removed by those streams which bore away the lighter loam, sand, and gravel.

Paleontologic Character

No fossils are known from the Sunderland of Anne Arundel County. Identifiable plant remains have been found at Point of Rocks, and near the headwaters of Island Creek, both in Calvert County. Among the forms found are representatives of *Quercus* and *Ulmus,* practically indistinguishable from certain oaks and elms which inhabit this region at the present time.

Thickness

The maximum known thickness of the Sunderland is about 80 feet. It will probably average somewhat over 30 feet for Anne Arundel County.

Stratigraphic Relations

Just as with the Brandywine, so with the Sunderland, overlap may bring the formation in contact with any of the underlying formations. In this county the Sunderland is found resting upon every older formation except the Choptank, which is present in only one very limited exposure. The Wicomico forms a fringe about the outer border of the terrace and penetrates it as a re-entrant in the valleys of the larger streams.

The Wicomico Formation

The term Wicomico formation is derived from Wicomico River in Southern Maryland. It was proposed by G. B. Shattuck[1] in 1901 and represents the upper part of what had previously been designated Later Columbia.

Areal Distribution

The Wicomico formation of the county is best developed along the Patuxent River, where it occurs in closely adjoining patches separated only by the erosion valleys of small tributary streams. The chief excep-

[1] Shattuck, G. B., Johns Hopkins Univ. Circ., No. 152.

tion is found in the area bordering the upper valley of the Little Patuxent where it is not found. Small patches of Wicomico are also found along Magothy and Severn rivers.

Character of Materials.

The material composing the Wicomico formation is similar to that of the Sunderland. It consists of gravel, sand, clay, peat, and often large ice-borne boulders, all grading into each other horizontally and vertically. The sands are often cross-bedded. These are usually covered by a brown loam, quite free from gravel, but containing occasional large boulders which are usually of igneous rock, especially gabbro. The character of the sands and clays depends largely on the region where they are examined, since they are composed of material derived with comparatively little change from the formations below. Thus in a Miocene area the sand is often fine; in an Eocene or Upper Cretaceous area it may contain considerable glauconite, while in a Potomac area sands when present are coarse and often contain an admixture of reddish clay. The gravel is obtained largely from the Potomac formation or from the Sunderland above.

Physiographic Expression

The Wicomico formation is developed as a terrace fringing the Sunderland above. The valleys of Wicomico time form re-entrants into the Sunderland terrace and often are of great width as compared with their length—an evidence of their estuarine character. As already pointed out, the scarp separating the Wicomico from the Sunderland is one of the most pronounced features of the Coastal Plain. Excellent examples of this, although of limited extent, are to be found at Woodwardville, and especially ¾ of a mile west of Omar. At both these localities the Sunderland is largely lacking, but the scarp rising abruptly at the limit of the former Wicomico sea is very striking.

The Wicomico has been subjected to considerable erosion at some localities and there presents a gently rolling surface. At other points, as

at Woodwardville, it is almost as flat to-day as on its first appearance above the level of the sea.

Paleontologic Character

No organic remains have been observed in the Wicomico of Anne Arundel County. The only locality from which Wicomico fossils have been obtained is Queen Anne (Hardesty), Prince George's County, where, in a deposit of carbonaceous material about 20 feet thick, impressions of grasses and stems together with some insect remains have been discovered.

Thickness

The maximum known thickness of the Wicomico is 70 feet at Turkey Point in Cecil County. The formation probably does not average over 20 feet for Anne Arundel County and is often much thinner.

Stratigraphic Relations

The Wicomico formation may rest upon any of the older formations of the county.

The Talbot Formation

The term Talbot formation is derived from Talbot County, on the Eastern Shore, where this terrace is especially well developed. The name was suggested by G. B. Shattuck[1] in 1901 to include the lower part of McGee's Later Columbia.

Areal Distribution

The Talbot formation is developed along the Patuxent River in closely adjoining patches as far north as Hill's Bridge. Like the Wicomico it is often found along the larger estuaries. Unlike the Wicomico, the Talbot is well developed along the bay shore. Two areas are of special note, since they are by far the largest and best preserved areas within the county. The first is that district composing what is known as "The Swamp," lying between South River and Rockhole Creek. The second area, typically developed though considerably smaller, is found towards the eastern extremity of the neck northeast of Annapolis.

[1] Shattuck, G. B., Johns Hopkins Univ. Circ., No. 152.

Character of Materials

The materials composing the Talbot differ but little from those of the other Pleistocene formations. Peat, loam, clay, sand, gravel, and ice-borne boulders are all found, often in one section. The relative proportion of these constituents depends very largely upon the lithologic composition of the formations from which they were derived. The Talbot seems to have differed somewhat from the earlier Pleistocene formations, at least in Anne Arundel County, in a greater predominance of swamp conditions. At almost every extensive exposure of Talbot within this county evidences of such conditions are found in beds of peat and the remains of huge cypress trees, either in the form of branches and "knees," or of great stumps now partially submerged but usually well above the water at low tide. Such sections are found a little over a mile below Bodkin Point; on the east shore of Gibson Island ½ mile north of Mountain Point; at Greenbury Point east of Annapolis; and at Saunders Point near the mouth of South River. The wide distribution of this type of deposit makes clear the extensive presence of swamp areas in Talbot time, especially when it is borne in mind that very similar conditions are shown in many sections in Talbot County just across the bay. Sections indicative of such conditions in the older Pleistocene formations are present in other areas, but seemingly are much less common than in the Talbot. This is certainly true for Anne Arundel County.

The bipartite division noted in other Pleistocene formations is also found in the Talbot. At times the upper loamy phase is predominant, as in the area known as "The Swamp."

Only a small portion of "The Swamp" is really swampy, and such portion is confined entirely to its margin or to the heads of the small coves which project into the land. It is so low and flat, however, that in the spring during heavy rains or during seasons of unusually high tides a considerable portion is at times covered with water. The materials are almost entirely a very fine loam. When wet it has a light drab tone, but when dry is of an ashy color, almost white. Because of the almost entire absence of sand it forms a very hard compact mass when dry. It is a

curious fact that scarcely a gravel is seen on the surface over the entire flat, and in the cliffs not a single one was found in the loam. The whole region is very thickly settled, more so than any other part of southern Anne Arundel County. Most of the people live by oystering.

Good sections are far more common in the Talbot than in the other Pleistocene formations. A few of these will be given:

Section between Parker's Island and the mouth of Herring Creek, "The Swamp"

		Feet	Inches
Pleistocene.			
Talbot.....	Fine loam, light drab below, ashy white above..	6	
	Coarse greenish-blue sand with some few gravel	1	6
	Yellow clay greatly iron-stained.....		4
Miocene.			
Calvert.....	Diatomaceous earth, exposed.....	1	
	Total thickness	8	10

Section at Bay Ridge, ⅜ of a mile southwest of Tolly Point

		Feet	Inches
Pleistocene.			
Talbot.....	Buff to yellowish-brown sandy clay loam grading downwards into next member.....	3	
	Greenish-gray to light brown sand, containing considerable glauconite	9	
	Pebble band in matrix of sand similar to sand above. Pebbles small, few exceeding 1 inch in diameter	8	6
	Gray sand containing considerable glauconite, pebbles of clay, and quartz pebbles.....		14
	Tough yellow clay representing the weathered portion of the clay below.....		6
	Black clay with stems of plants and trees, some layers consisting of quite pure peat with beetle wings, and a few small quartz pebbles..	3-6	
	Bright green sand containing much glauconite with pockets of gravel and some bands of iron stone	3-4	
	(In one place two boulders over 1 foot in diameter occur in this layer. Glauconitic sands belonging to the Eocene rise above water at the center of the bluff.)		
	Total thickness 28-32		2

Section at Greenbury Point, Severn River

		Feet	Inches
Pleistocene.			
Talbot.....	Yellowish-brown clay loam containing a few small pebbles	5	
	Bright olive-green sandy clay, very hard.....	1	6
	Brown to gray sand argillaceous in places, containing single pebbles and pebble bands.....	6	6
	Pebble ironstone conglomerate		3-6
	Plant bed, a black compact clay with some moulding clay containing plant stems and huge cypress stumps exposed at high tide....	4	6
	(Some of the stumps showing in the water about 20 feet from the shore are fully 8 feet in diameter.)		
	Total thickness	17	9-12

Physiographic Expression

The Talbot formation comprises the lowest of the terraces developed along the Middle Atlantic Slope. Since it is the lowest and also the youngest, the factors working towards the destruction of its original character have been reduced to a minimum, and as a result the flat featureless topography of a land recently raised above the sea is here preserved in a striking manner. It furnishes a connecting link so clear as to leave no possibility of misinterpretation between the recent deposits and the older, more dissected terraces.

The Talbot formation forms a fringe around the edge of the Wicomico above, and occasionally around the Sunderland when the Wicomico is lacking. It penetrates the upper terrace in the form of re-entrants which clearly mark the lines of a former well-marked drainage, although at present these valleys often play a very subordinate part in the topography.

Paleontologic Character

The Talbot formation is the most fossiliferous of the Pleistocene formations. In Anne Arundel County it has yielded plant remains and at Bodkin Point the casts of *Unios*. Three fossil localities are known in the county, the first at Bodkin Point, the second at Bay Ridge, and the third

at Fairhaven. The most fossiliferous locality anywhere known in the Talbot is found at Wailes Bluff, Cornfield Harbor, St. Mary's County. The following list of forms from Anne Arundel County is collected from the descriptions in the Pliocene and Pleistocene Volume of the Maryland Geological Survey:

Osmunda sp.? (Swamp Fern), Tolly Point (Bay Ridge)
Fagus americana Sweet (American Beech), Bodkin Point
Nyssa biflora Walter (Water Tupelo or Gum), Bodkin Point
Pinus echinata Miller (Yellow Pine), Bodkin Point
Pinus strobus Linné (White Pine), Bodkin Point
Robinia pseudacacia Linné (Locust), Bodkin Point
Taxodium distichum (L) L. C. Richard (Bald Cypress), Bodkin Point
Vitis sp. (Grape), Bodkin Point
Xolisma ligustrina (Linné) Britton (Privet Andromeda), Bodkin Point

Thickness

The maximum thickness of the Talbot formation is very little over 40 feet. In Anne Arundel County it does not average over 20 feet, and very often thins down to a mere veneer covering the underlying deposits.

Stratigraphic Relations

The Talbot supposedly lies unconformably on the outer edge of the Wicomico terrace, although the great similarity of materials has made it impossible to identify absolutely any such relation. The Talbot is usually separated from the Wicomico and also from the Recent deposits by a scarp. It is to be noted that the Talbot and Recent at times grade into each other by gentle slopes with no sign of a sea cliff. In fact the sea is often building up land in the form of bars instead of cutting a cliff.

The Recent Deposits

The Recent includes all those deposits laid down from the end of Talbot time to the present. It is the period in which we now live and furnishes the criteria on which are based the theories of conditions in past geological time. Although some terrestrial deposits must be included here, aqueous deposits are in this area of far greater importance.

Mention has continually been made in the preceding paragraphs of the removal of this or that formation from certain areas, or of its more or less complete dissection. This means that the deposits have been transported to some other locality, and since the composition of the materials composing these deposits is largely insoluble in surface waters, there has been little physical change during transportation. To discover what is being done with the removed material is not difficult—even a casual observer may see that it is being carried away by the streams which bear it as far as their currents are swift enough to hold it in suspension. When their currents are checked, the material is deposited. Evidence of this is found at the mouth of every stream in the county. It is perhaps most commonly evidenced by the smaller creeks which empty into such estuaries as the Severn. The inhabitants of the county all bear witness to the deeper conditions which formerly prevailed along these minor creeks. As a concrete example, take the inlet just east of Little Round Bay. The topographic map shows a swamp developed at its head. This is a wide reed-covered slimy morass, almost impassable. Even the inlet below the swamp is very shallow and is being rapidly encroached upon. Yet a reliable man, a native of the region, states that 25 years ago lumber was loaded directly on boats which penetrated inland ¼ of a mile above the present head of the swamp. This is not an exception, but the general condition. To see that this is not limited to the minor creeks it is only necessary to note the pronounced filling which is accumulating in the Patapsco. Fifty years ago this stream was navigable with much more freedom than at present—to realize this it is only necessary to call to mind the former accessibility of Elkridge Landing.

In addition to the filling of the smaller streams, the larger rivers are continually bearing material into the bay and depositing it along the shores, especially near their mouths. While this material is distributed over a large area and does not accumulate so rapidly as in smaller streams nearer the source of supply, it is, nevertheless, a process always active, and the constant dredging necessary along the bay in order to keep the channels open to navigation bears witness to its effectiveness.

The active erosion of the waves along certain portions of the bay shore is also an important factor in building up the Recent deposits.

The material thus gained by stream and wave action is more or less sorted and spread over the floor of the rivers and bay. The depressions left by the late Talbot sinking are being filled in and a level terrace-like basement is being built up. The materials furnished by the rivers consist mostly of various kinds of sand and clay which, during their long transport, become intermingled and lose much of their original individuality. Much of the wave-derived material, on the other hand, is deposited comparatively near the source of supply and the lithologic character of the Recent deposits in this case depends largely on the formation composing the sea cliff. Where this contains much gravel, the Recent deposits will also contain much gravel; where it is glauconitic, they will be glauconitic; where argillaceous, they will be of mud; where formed in an imponded stream, deposits of peat may be expected. This is just what has gone on in past geologic periods, and while this is not the place for details it is evident that a careful study of the phenomena of the Recent stage is essential to an understanding and interpretation of the geological records of the past.

INTERPRETATION OF THE GEOLOGICAL RECORD

The following attempt to picture the physical conditions under which deposition took place in the various formations of the Coastal Plain and to decipher the meaning of the geological record revealed in these beds, is based on whatever facts have come to hand and is by no means restricted to observations from such a limited area as Anne Arundel County. Although opinions may differ as to the exact interpretation of certain features to be discussed, the general trend of events as outlined below is such as is accepted by most geologists who have worked in the Coastal Plain.

SEDIMENTARY RECORD OF THE POTOMAC GROUP

West of the Coastal Plain lies that great mass of ancient and highly metamorphosed rocks which compose the Piedmont Plateau. These have been above the sea since very early geologic time and have passed through

many vicissitudes of folding and erosion. Among the erosional phenomena has been a series of four reductions to approximate base level; the earliest and most extensive of these is known as the Schooley Peneplain, and was probably formed in Jurassic time; next was formed the Weverton peneplain, of either late Jurassic or early Cretaceous age;[1] following these came the Harrisburg and Sommerville of Early and Late Tertiary time. These are interesting at this point from the fact that the Schooley and Weverton peneplains—possibly the Weverton alone—prepared the way for the deposition of the sediments of the Potomac group, for after the old Archean rocks had been reduced to base level in the Jurassic, an uplift with tilting towards the east took place which allowed a transgression of the sea and at the same time caused a rejuvenation of the rivers, renewed active erosion, and produced rapid deposition. Thus was inaugurated the sedimentation of Potomac time.

As has been brought out in the description of the formations composing this group, it is characterized by extreme lithologic variability. Coarse gravel, sand, and clay exist in close horizontal proximity. Cross-bedding is common. Numerous plant remains are found, varying from comminuted leaf fragments through leaves and twigs to great lignitized and ferruginized trunks. Occasionally the remains of great land animals are found. All of these conditions are such as are duplicated to-day in continental deposits, in delta deposits at the mouths of great rivers, in estuarine deposits, and partly at least in near shore marine deposits. The great extent of the Potomac beds is against their origin purely as delta deposits. Although the estuarine origin of the deposits is usually assumed, it is possible that this has been over-emphasized.

The beds first to be deposited were made up largely of materials drawn directly from the long exposed and much weathered surface of the crystalline rocks. Prominent among these constituents were quartz, clay, and arkose. Arkosic sand is especially characteristic of the basal Potomac formation, the Patuxent. Gravels and clays were also brought down by the rivers, but the sands predominate.

[1] Md. Geol. Survey, vol. vi, pp. 76-77.

After erosion had proceeded for some time the land surface was again lowered, though not to its former level, so that the lower courses of the streams running across the Patuxent surface became areas of swamp land. In these were laid down that series of clays and iron ores which is called the Arundel formation. It is evident that such a formation must be composed of a series of lenses rather than of one continuous sheet of deposits, as is the more usual conception of a formation. After a considerable body of these clays had been laid down the land again rose and both the Patuxent and Arundel were subjected to erosion as is proven by the unconformity with the Patapsco formation above. Then once more a sinking began, and continued until the Arundel and large parts of the Patuxent had been again submerged.

The Patapsco formation, thus inaugurated, is a formation dominantly argillaceous, although beds of very homogeneous clean sand may occur. The physical conditions of deposition were evidently quite similar to those of the Patuxent. For the first time the remains of undoubted dicotyledonous plants are found, but the flora as a whole is closely related to that of the older Potomac formations. The Patapsco sediments were the last to be laid down in Potomac time. When the land rose and Patapsco deposition was ended, equilibrium apparently reigned throughout this section of the continent during a long period, for by the next submergence dicotyledons had so developed as to be the dominant forms and were of an Upper Cretaceous type.

SEDIMENTARY RECORD OF THE UPPER CRETACEOUS FORMATIONS

As has already been emphasized, the Upper Cretaceous opened with conditions similar to those which had held sway in the preceding Potomac epoch. The sands, gravels, and clays of the Raritan differ little from those of the Patapsco. The clays of the Raritan are as a rule less highly colored than those of the Potomac group. Certain parts of this formation, as the glass sands and pottery clays along the Severn River, are exceedingly free from iron. The great contrast between the Raritan and the Potomac group is furnished by the abundance of dicotyledonous plants in the former.

After a time the deposits of Raritan time were lifted above sea level and subjected to erosion. Streams began to wear away the easily-eroded materials and considerable valleys were cut. This is well attested by the pronouncedly undulating unconformity which separates the Raritan from the overlying Magothy formation. When the land again sank and deposition began once more, what is now designated Magothy time was introduced. At the opening of this age conditions similar to those of the Potomac epoch prevailed. Very variable deposits of sand and clay and some gravel were laid down. Many decayed stems and trunks were buried and now appear as lignite, while the gums secreted by them are found scattered through the deposits in the form of amber. In the quieter waters leaves sank to the bottom and were covered by clay. Occasional pockets of glauconite are found. If estuarine conditions prevailed, incursions of the sea must have taken place for glauconite is wholly of marine deposition. Farther north, in New Jersey, strictly marine invertebrate remains are found. In Maryland the near-shore and estuarine character of the Magothy seems to have persisted to the close of the age. Viewed broadly, the Magothy was evidently a time of transition towards the undoubted marine phase which was to characterize the remainder of the Coastal Plain formations.

The Magothy was terminated by an uplift which brought the recently deposited sediments at least partially above water. The amount of erosion to which these were subjected seems to have been variable. At some points there is little to mark the line of contact between the Magothy and Matawan and deposition was probably continuous. In other cases, as along the Chesapeake and Delaware Canal and the western shore of Little Round Bay the contact is extremely undulatory; the Magothy may rise several feet above tide, appearing and disappearing several times in a short distance.

When the land once more sank, truly marine conditions, such as are usually associated with the Upper Cretaceous, were ushered in. The sea of this time was more extensive than that of the Magothy, for the Matawan is sometimes found resting directly on the Raritan at points where there

FIG. 1.—VIEW SHOWING GRAVEL PITS IN THE WICOMICO FORMATION AT BRAGERS, W. B. & A. R. R.

FIG. 2.—VIEW OF A PIT OF THE WASHINGTON HYDRAULIC PRESSED BRICK COMPANY, 1 MILE SOUTH OF HARMANS.

is no reason for supposing the removal of pre-existing Magothy deposits. The deposits of the Matawan are rather uniform mixtures of sand, clay, glauconite, and mica, although the mica is somewhat variable in amount.

The region most favorable to the formation of greensand is near the boundary between the Shallow-water and Deep-water zones, *i. e.*, at a depth of about 100 fathoms. The maximum depth is about 900 fathoms. From this certain deductions may be drawn as to the conditions of deposition of the Matawan, namely, that it was laid down under fairly uniform conditions, but too near the shore to furnish ideal conditions for the formation of glauconite. Such a conclusion is borne out by the large amount of lignite sometimes found in the Matawan. It is interesting to note that in the Matawan at Millersville, Anne Arundel County, a specimen of *Dammara borealis* Heer has been found, which is closely related to a Magothy form and shows here also the close relationship of these formations. In addition to this, the writer found in 1909, in the concretions of the Woodbury clay at Lorillard, New Jersey, a leaf of *Ficus* sp., also closely related to a Magothy form. This bears further evidence to the close union between the Magothy and Matawan formations throughout the entire area of deposition and adds probability to the idea that the unconformities found are only of local importance. The sequence of events, therefore, would be, first the estuarine and near-shore deposits of the Magothy, then a slight uplift bringing local areas above tide, followed by a renewed advance of the sea and the deposition in many localities of the Matawan formation as a series of beds continuous with those of the Magothy below. This sinking continued without a conspicuous break into Monmouth time. Deeper conditions prevailed however, for the Monmouth transgresses the Matawan. Conditions were evidently more favorable for the unhampered production of glauconite which, with sand, composes the formation. This type of deposits must have had its contemporaneous near-shore equivalent, but this has been entirely removed, or else is undifferentiable from the formation below.

This completed the history of Upper Cretaceous sedimentation, so far as Anne Arundel County is concerned. To the north, and especially in

New Jersey, two additional formations, the Rancocas and Manasquan, were laid down, both continuing the general physical conditions just described. Conditions were even more favorable for the formation of glauconite and none of the Maryland beds can approach these in the purity of this deposit. It is possible that these highest Cretaceous formations were laid down in Anne Arundel County; if so, they were removed during the period of erosion preceding the deposition of the Eocene. There is an equal possibility that uplift ended the period of Cretaceous deposition sooner in this area than in the region to the north, and that sediments corresponding to the Rancocas and Manasquan were never laid down in this county.

SEDIMENTARY RECORD OF THE EOCENE FORMATIONS

When the land again sank after the Upper Cretaceous uplift, there was an immediate return to conditions very similar to those which had prevailed during the latter part of Upper Cretaceous sedimentation. Glauconite was formed in large quantities and was intermingled with deposits composed largely of sand. Large numbers of Mollusca and Gastropoda swarmed in this Eocene sea. These conditions continued until about the middle of Eocene time, when there was a pronounced change which caused the sedimentation to take on the most argillaceous character developed since the Magothy. This was at the ushering in of Nanjemoy deposition with its locally developed unfossiliferous and non-glauconitic clay. It is difficult to explain this bed of homogeneous pink clay. It may be explained as due to a shallowing of the sea which brought a fringe of deposits above shore as a low-lying plain across which the rivers meandered to the sea and deposited beds of clay. This hypothesis is borne out by the fact that the thickest beds of clay are found towards the landward margin with, so far as can be determined, decrease in thickness down the dip. Whatever be the explanation of the clay, the conditions governing its formation were of short duration, and there was soon a return towards the conditions of early Eocene time with the formation of glauconite. The return to the former state was not complete, however, for the glauconitic sands contain a much larger per cent of clay than did those of the Aquia.

Molluscan life, though abundant, does not seem to have been so profuse as in the earlier history of the period. These conditions, as represented along the Middle Atlantic Slope, persisted with little change to the end of Eocene time.[1] The uplift which terminated the period in Maryland brought to a close those conditions which had persisted rather closely since the beginning of the Matawan.

SEDIMENTARY RECORD OF THE MIOCENE FORMATIONS

The Miocene was a time of deposition of clays, diatomaceous earth, and fine sands. These conditions can be accounted for by supposing that the subsidence at the beginning of this epoch produced a coast of low relief off which sluggish streams, usually too slow-moving to bear coarse sand, not to mention gravel, gradually deposited their loads. The presence of diatomaceous earth, formerly thought to indicate deep waters, is satisfactorily accounted for if freedom from sedimentation is assumed in some quiet basin. This condition was best fulfilled at the beginning of Miocene time. Throughout most of the epoch, conditions seem to have been extremely favorable for molluscan life, as is testified by the great abundance of their fossil remains.

When Miocene sedimentation was completed, and the uplift which terminated it had taken place, a final end was put to this and the preceding types of deposits; before the deposition of the next sediments conditions which made possible those deposits known as "surficial" were introduced and have continued to the present.

SEDIMENTARY RECORD OF THE BRANDYWINE FORMATION

The sedimentation of Brandywine time was ushered in by conditions different from any of those preceding. They resembled most closely those prevailing at the opening of Patuxent time, for during the Miocene uplift erosion had proceeded so far that the land was nearly base-leveled. Then, just as in Patuxent time, at the very opening of Coastal Plain history,

[1] Younger Eocene sediments have an extensive development in the South Atlantic and Gulf states.

this peneplain was tilted towards the sea and the streams rejuvenated. These brought down deposits of gravel which were spread along the shore. At the same time the waves were at work pushing back the shore line. The rivers emptied the heavier part of their load here so that as the shore line retreated it was followed by an almost continuous sheet of gravel. This operation may have been assisted by a slight progressive sinking of the land. While the gravel and boulder layer was gradually making its way farther and farther west, on its outer margin the finer load of the streams was being deposited as evidenced by the capping of loam which is found to-day so extensively and uniformly developed over the coarser materials.

The general trend of this time, viewed both from the destructive work of the waves in cutting back a cliff and from the constructive work of the deposits near shore, was to form a comparatively level series of deposits. As soon as the beds were raised above sea level, erosion set in and dissected them to a considerable degree. Then the sea again advanced and the Pliocene period as developed in this region was ushered in.

SEDIMENTARY RECORD OF THE PLEISTOCENE FORMATIONS

So much has been said concerning Pleistocene history in the discussion of the topographic history of the county that little need be repeated. It has been pointed out that by careful study a series of terraces can be discovered, each terminated by a scarp which runs across the country for miles more or less continuously, and each successively lower than the one preceding and at very nearly a constant level. Each of these elevated terraces and cliffs is ascribed to an advance of the sea, the westernmost limit of the sea being in each case the point at which the old sea-cliff (scarp) is found. It is evident that the highest terrace must be the oldest, for it is the greatest in extent, and if younger than the others would have submerged them and destroyed all traces of their former existence. The same argument may be advanced for each terrace in reference to those lying below it. The record of Pleistocene events was, then:

First, the deposition of gravels, sands, clays, and ice-borne boulders along the margin of the sea and in the greatly enlarged estuaries, accompanied by the cutting of a cliff along the margin of the sea. *Second,* the elevation of these deposits approximately parallel to themselves, and the subjection of these deposits to erosion. *Third,* another but lesser advance of the sea, with the beginning of deposition of another series of deposits.

Since three terraces are known this cycle must have been completed three times. The first cycle resulted in the formation of the Sunderland terrace, the second of the Wicomico, and the last of the Talbot. Conditions were very similar during all this time, but as pointed out earlier, the Talbot seems to have been an age during which the land lay nearer water-level than in the others, as evidenced by the greater number of typical swamp deposits found.

From the above account it is evident that considerable is known concerning the remote past of Anne Arundel County. Conditions have been far different from what they are at present. The whole of the county has often been under water and when, as in the time represented by the unconformities there has been land, its extent and configuration have been quite different from what obtains at present. Indeed, only until very recent geologic time, in the latter half of the Pleistocene, did the county take on anything like its present form. Under these circumstances much room is left for the play of fancy, and many interesting pictures of past conditions can be created. The writer has attempted to keep close to certainty in most of the interpretations given; to the reader is left the pleasure of filling in the gaps as may seem to him most concordant with the facts presented.

THE MINERAL RESOURCES OF ANNE ARUNDEL COUNTY

BY

HOMER P. LITTLE

Introductory

The mineral resources of Anne Arundel County include none of the so-called precious metals nor any gem stones. They are confined almost entirely to structural materials as gravel, sand, clay, and a limited amount of stone; and to marls, diatomaceous earth, and iron ore. Although these materials, especially the structural ones, are not of great value in limited amounts, yet the almost inexhaustible supply of some of them coupled with the proximity to Baltimore, enhances their value greatly. Although the "sands of Anne Arundel" are often spoken of somewhat contemptuously, the fact remains that many a good fortune lies waiting those who will develop them, as is being gradually discovered. And this holds for other of the natural resources of the county.

The Natural Deposits

THE CLAYS

The following paragraphs on the clays of Anne Arundel County are largely based on the report by H. Ries, on "The Clays of Maryland," Volume IV of the Maryland Geological Survey.

The Potomac Clays

All of the Potomac formations contain clay of commercial value but in greatly varying amounts.

The clays of the Patuxent formation within this county are of little importance; in fact only one locality is known where development is at

all likely, namely, on the H. Brown estate at Timberneck on Deep Run. There the clay is probably 10 feet thick and of considerable horizontal extent. According to Ries it is of a refractory nature, fusing slightly above cone 27.

The clays of the Arundel formation are of much more commercial value. These clays, mostly blue and somewhat siliceous, are of good plasticity and are used for the manufacture of common and pressed brick, terra cotta, roofing tile, and common pottery. The common presence of nodules of iron carbonate may make it necessary to put the clay through rolls in order to exclude them. The chief occurrence of Arundel clays in the county is, as will be seen by reference to the geologic map, along the northwest boundary. Here are enormous masses of clay. The chief objection to them is that the iron ores are usually very abundant; however, clays of better grade, free from iron ore, are at times found. Little advantage is being taken of these deposits, although the clay of an abandoned iron mine 1½ miles east of Laurel has been dug for the manufacture of brick. A very plastic red-burning potter's clay occurs on the property of Charles Needer, 1 mile northeast of Patapsco Station.

The Patapsco clays are more extensively worked in Anne Arundel County than those of any other age. The development in proportion to the supply is, however, very meager. The typical variegated "terra cotta clay" especially, which occurs in unlimited amounts suitable for the manufacture of brick, is almost untouched. This was at one time dug near Glenburnie and manufactured into tiling, but for some reason the venture was not a success, though apparently through no fault with the supply. The higher grade Patapsco clays are less common in the county. However, a good quality blue clay was dug for years on the estate of Frank Hancock, 1½ miles south of Hawkins Point, and shipped to the Bennett Pottery Company of Baltimore until forced out of the market by competitors who could supply at a lower rate.

A type of Patapsco clay adapted to the manufacture of smoking pipes is mined at a point about ½ mile south of Wellhams on the Annapolis Short Line. An important deposit of gray-black gritty clay, located

about ½ mile south of Harman on the Pennsylvania Railroad, has been worked for some years by the Washington Hydraulic-Pressed Brick Company. The deposit is favorably located and considerable operations are going on. Deposits of a white clay are found 1 mile and 2½ miles south of Glenburnie. The former has been used in the manufacture of buff brick. The latter, occurring on the H. T. Wade estate is quite refractory, for it is not vitrified at cone 27.

The Upper Cretaceous Clays

The only clay-bearing formations of this group are the Raritan and the Magothy. The Raritan clays are well developed in Anne Arundel County, especially along the Severn River. Operations, however, have declined. Various localities where workable Raritan clays are found are given in Volume IV, Maryland Geological Survey, pp. 407-413. It is to be noted that many of these are regarded as Patapsco in the present report. True Raritan clays of considerable extent are found below Bodkin Point on the bay shore, where they are easily accessible. A white clay occurring at Earleigh Heights, suitable for the manufacture of white bricks and refractory ware, is worthy of notice. This clay is barely vitrified when heated to cone 27.

Certain clays of the Magothy formation are suitable for the manufacture of pressed brick and terra cotta, and might also be of value in the manufacture of paving brick if mixed with some other clay of the region. Deposits of this sort are found on the Magothy River at Swan Cove. The clay deposits of this formation, as it is developed in Anne Arundel County, are confined largely to Magothy and Severn rivers.

The Eocene and Miocene Clays

The only Eocene clay of any commercial value is the Marlboro clay at the base of the Nanjemoy formation. Only one deposit of any importance—and that not utilized—occurs in Anne Arundel County. This is found at the point where the road from Davidsonville to Annapolis crosses the upper course of Beards Creek. The Marlboro clay is a fine-

grained red material, fairly plastic, suitable for pressed brick and possibly for the manufacture of paving brick.

The Miocene contains no important deposits of clay. The diatomaceous earth of this period, though resembling a clay in appearance, is not really such, and will be discussed under a separate heading.

The Brandywine and Pleistocene Clays

The Brandywine formation contains in some counties clays suitable for the manufacture of brick. In Anne Arundel, however, the formation is so sparingly developed that it is of no value whatever.

The clays of the Pleistocene are never used for anything except common brick. These clays have not been utilized in Anne Arundel County except to a very limited degree, and it is probable that those of the Sunderland and Wicomico formations never will be because of the amount of sand present. The Talbot, however, contains deposits which offer distinct possibilities in the area south of Bodkin Point. Ries has tested these carefully and finds them of good plasticity. They burn to a good red color, and the only objection seems to be a rather high shrinkage. The fact that this material, which is large in extent and so easily accessible to Baltimore City, would probably lend itself to the manufacture of paving brick, should give it an added importance. A greenish-drab clay at Greenbury Point, Severn River, is said to be used at the Naval Academy for moulding purposes and to be especially desirable because so very hard when dried.

THE SANDS

There are three principal classes into which the sands of Anne Arundel fall: First, building sands; second, glass sands; third, moulding sands.

The moulding sands have not been developed, but several prospects have been opened. These lie near the head of Saltworks Creek, Severn River, and are in the gray-green glauconitic sands of the Monmouth formation. According to information obtained from local inhabitants, some of this sand was shipped to Baltimore for moulding purposes and a deal

for the purchase of the beds nearly consummated. For some reason, however, this did not materialize.

The chief occurrences of glass sand in the country are found along the banks of Severn River. Similar but less extensive deposits are found on Magothy River. All of these deposits occur in the Raritan formation. The only active operations at present are at the pits of the Brennan Sand Company, just west of Forked Creek. In 1908 a strip about 10 feet in thickness was being removed. Borings showed the glass sand to extend downwards about 30 feet more. Of the remaining 47 feet penetrated, much was a good building sand, although one clay lens 10 feet thick was encountered. Formerly this sand was removed by tunneling, but at present the overburden is removed and an open-pit method employed.

Building sands are developed in Anne Arundel County in enormous quantities, and their value is becoming more and more appreciated. They are confined largely to the Potomac group, to the two lower formations of the Upper Cretaceous, and to the Talbot. They are all very similar in character.

Considerable openings have been made in the Patuxent formation 1 mile east of Laurel, from which it is said the material for the grading of the grounds about the new Union Station at Washington was taken. This material inclines to be gravelly, especially in an opening ½ mile north-northwest of the one just mentioned. Much of it, however, is of the usual texture of building sand.

The Patapsco sands are very accessible to Baltimore. The chief operations in this formation are those of the Rayner pits at South Baltimore. An opening has been made ½ mile south of Stony Run Station, much of the product being shipped to Arlington.

The most extensive supply of sand in the county is probably that of the Raritan. Large pits are found in this formation towards the head of both Severn and Magothy rivers, especially on the latter, where whole headlands have been removed. A large pit, well equipped with gravity haul, is that of W. F. Clarke, 1 mile south of Severn Station on the Pennsylvania Railroad. The walls have in places a vertical height of 25 feet and the lower limit of the sand has not been reached.

Sands have been dug from the Magothy formation by Captain Jeff Cook along Cornfield Harbor, near the mouth of Magothy River, and are said to be of good quality.

The Talbot sands are chiefly exploited at present along the eastern shore of Marley Creek. One of the largest pits in the county, that of Wm. R. Della, is located along this creek ¾ of a mile north of Marley. This pit has been in operation for six years and has furnished a large amount of high-grade sand. A smaller pit is located 1¼ miles north of here. Similar deposits, though of much less vertical thickness, were formerly worked near the mouth of Furnace Creek along the south bank, but are now abandoned. The sand-digging industry, however, is at present one of the most flourishing of those which involve the mineral resources of Anne Arundel County.

It should not be overlooked in this discussion that these sands, forbidding and desolate as they may appear to one unfamiliar with their possibilities, are wonderful trucking grounds and raise many types of produce with great success. A rapid influx of industrious Germans is bringing about the development of hitherto unused lands, and the sandy fields of Anne Arundel are constantly adding increased wealth to the county.

THE GRAVELS

Outside of the Pleistocene formations no gravel deposits of any importance are found in Anne Arundel County. The largest supplies are found along the Patuxent River. The most accessible of these deposits are those developed in the Wicomico formation by the Washington, Baltimore and Annapolis Railroad at the points where it crosses the Big and Little Patuxent rivers. A good quality of gravel, but only 2 to 3 feet thick, is being removed from the surface of the Wicomico plain ¼ of a mile west of Woodwardville. The supplies most available for Baltimore are found in the Sunderland formation at South Baltimore and are being worked in connection with the Rayner sand pits. In contrast to the deposits previously mentioned these contain a large amount of ferruginous matter, and the material is often cemented to a conglomerate. Small openings have been made in similar materials along the road about 1 mile

east of Patapsco Station. In fact, that large area of Sunderland extending from South Baltimore westward through Linthicum and Shipley to near Patapsco Station is almost everywhere underlain by a good quality of ferruginous gravel 8 to 10 feet thick, well adapted for use as road metal.

THE BUILDING STONES

The supply of building stone in Anne Arundel County is extremely limited, as would be expected in a Coastal Plain region. There are, however, two stones which are somewhat used—the Raritan and Patapsco brown indurated ferruginous sandstone and the Raritan white quartzose sandstone. The former is the more common and is quite widely used in some regions for underpinning. Although iron cemented it seems to be quite durable. One house just north of Cattail Creek, Magothy River, whose every line shows it to be one of the oldest of the region, is built entirely of this stone—or possibly of Magothy sandstone—and is in most excellent condition. A church located 1½ miles east of Jessups Station is constructed of similar material.

The white quartzose sandstone has been little used in the construction of buildings even where occurring in large masses, due probably to its great hardness and the consequent difficulty of working. In Prince George's County, about 1 mile west of Priests Bridge, a chapel has been built of this material. A deposit in Anne Arundel County, ¾ of a mile north of Lemons Bridge, was used in the construction of railroad culverts over the Patuxent. The largest deposit in the county occurs ½ mile east of Elvaton. Little use is made of this, although quarrying to a small extent has been carried on in the past.

The brown ferruginous sandstone occurring in the Magothy and Eocene formations is occasionally used as underpinning and in minor construction, but is of little importance.

THE MARLS

Marl in general is divided into two classes, shell marl and glauconitic marl. The former depends on the presence of calcium carbonate for its beneficial action, the latter essentially on the presence of potash. The

fact that in these latter, calcium carbonate from contained shells and phosphates from mineral phosphates are also usually present, gives them an additional value.

Shell marls are practically lacking in Anne Arundel County. The glauconitic marls, on the other hand, are exceedingly abundant throughout all that large area in which the Monmouth and Eocene formations are present. The black marls of the Matawan, though not so rich in glauconite, also fall into this class. When one considers the tremendous amount of this material available, the ease with which it is dug, and the great benefits derived through its use, as witnessed by many competent observers, it seems remarkable that no more advantage is taken of this great natural resource. Especially is this true when it is borne in mind that Anne Arundel is a county whose lands have long been under cultivation and throughout which many farms are falling into decline, while others have been totally abandoned because of exhaustion of the land.

THE DIATOMACEOUS EARTH

Diatomaceous earth is a substance clay-like in appearance, but in reality composed largely of the siliceous skeletons of microscopic plants known as diatoms. It is used as an absorbent in the manufacture of dynamite and as a base for polishing compounds; its nonconductivity of heat makes it useful as a packing for steam boilers, pipes, and especially for safes.

Large deposits of diatomaceous earth are developed at the base of the Calvert formation, and these appear in force in the southern part of Anne Arundel County. Owing, however, to the limited demand for the material at present, only one company is at work. This is located at the mouth of Lyons Creek on the Patuxent River and has its principal workings just over the line in Calvert County. Similar deposits which may prove of importance, if the demand for the earth increases, are found along Herring Bay at the extreme northern end of the Calvert Cliffs.

THE IRON ORES

The iron ores of Anne Arundel County, though little utilized at present due to greater and more easily worked supplies elsewhere, have been in

the past a source of considerable wealth, and in the event of a future exhaustion of deposits now worked will certainly once more take an important place among the natural resources of the county.

The iron deposits really belong to two quite different types, which may be called the iron ores proper and the paint ores. The former occur largely in the Arundel formation. Two varieties are common—the carbonate, or "white ores," and the hydrous oxide, or "brown ores." The northwest edge of the county is dotted with abandoned iron mines. One mile south of Portland Station is an old furnace which certifies to the past activity of the region in that its slag has been used for road metal. The clays of the Arundel have by no means been exhausted; in fact, their supply has apparently been scarcely touched. As evidence of the abundance of iron in these clays there was called to the writer's attention a well recently dug about 1 mile east of Patapsco from which over 500 pounds of ore was removed. This found a ready market at Muirkirk.

The paint ores are clays exceedingly rich in hematite, and occur quite commonly near the base of the Patapsco formation. The only active operations in the county at present are being carried on by William Dagler near the old Reynold's mine, $\frac{3}{4}$ of a mile south-southeast of Hanover. A deposit of paint ore about 1 foot in thickness outcrops in the road $\frac{3}{4}$ of a mile south of Patapsco Station. What is perhaps the same ledge outcrops $\frac{1}{4}$ of a mile south of Patapsco, but contains a much greater proportion of clay.

THE PETROLEUM AND NATURAL GAS

Various rumors occur from time to time of the finding of natural gas within the county. A boring was made about 2 miles west of Annapolis on such a rumor, but without results. In a well dug near the brickyard on the north bank of Curtis Creek near the road, it was reported that a strong odor of gas was noticed and that on lighting a match ignition took place and the gas burned with a feeble flame. This was at a shallow depth —only about 15 feet—and probably was marsh gas that had its source in a Talbot peat bog. It is quite certain that gas or petroleum in amounts economically valuable will never be found in Anne Arundel County.

THE LIGNITE AND PYRITE

Although not of commercial importance at present, the deposits of lignite and pyrite occurring at North Ferry Point, Magothy River, were once of much significance. Ducatel, in the Transactions of the Maryland Academy of Science, Volume I, 1837, wrote:

"The deposits of lignite and pyrites, already referred to as occurring at Cape Sable [North Ferry Point] on the Magothy, furnishes the material from which large quantities of alum and copperas are annually manufactured for the supply of nearly the whole Union."

These workings have all been abandoned for years, and due to the abundant supplies now at hand for the production of both alum and copperas, it is scarcely probable that these deposits of Anne Arundel County will again become valuable.

THE WATER RESOURCES OF ANNE ARUNDEL COUNTY

SPRINGS

Springs are very abundant throughout much of Anne Arundel County. Many of the springs utilized as such are scarcely worthy of the term, however, consisting merely of seepages of water into holes dug through a thin covering of sand to a clay bottom. Yet such springs are frequently utilized in spite of the danger of surface contamination. They serve to bring out the fact that the numerous alternations of sand and clay in the county furnish conditions very favorable to the formation of springs.

The two horizons at which springs are most often found in this county are at the contact of the Potomac and Pleisetocene formations and just below the contact of the Matawan and Monmouth formations. The water of the former is usually cool, clear, and tasteless; that of the latter, though often containing iron, is seldom disagreeable in springs, though in deep wells it may be entirely useless. The springs from this latter horizon are extremely abundant, and in the area of the Matawan-Monmouth contact many of the inhabitants depend wholly upon them for their supply.

Springs are of course found at other horizons, especially intraformationally in the Potomac group, where there are rapid alternations of sands and clays, but the two most constant occurrences are those cited above.

SHALLOW WELLS

In the southern half of Anne Arundel County the whole region is covered to a large extent by the surficial deposits, especially those of the Sunderland, although towards the Patuxent valley the Wicomico and Talbot are well developed. The supply of most of this region is procured near the base of these surficial deposits where their gravel beds rest upon the less permeable beds below. The depth of the wells, then, varies as the thickness of the Pleistocene covering, ranging rather constantly from about 15 to 35 feet. On some of the high narrow divides it is necessary to go as deep at 100 feet for a supply of water. Although the supply of these wells is closely dependent on the downward percolation of meteoric waters and is thus governed by the rainfall, yet because of the usual absence of extended droughts the supply of water is quite dependable.

North of this area the surface deposits disappear and the depth to which wells must be dug depends on the distance to be penetrated before some porous stratum, suitable for carrying water, can be reached. At Chesterfield the wells run 60 to 80 feet deep. Those living at a lower level depend for their supply largely on the springs which issue from near the top of the Matawan. About Millersville, especially along the road to the west, the inhabitants use driven wells largely, averaging 120 to 135 feet deep, pumping the water by means of gasoline engines. To the west of the station a very fine water is obtained in dug wells at a depth of about 70 feet. The source of this water seems to be the Raritan, perhaps near the contact with the Patapsco.

Across the Severn in the region of Arnold, dug wells run 25 to 100 feet. These shallow towards the bay, where some are only 12 feet deep. Throughout the whole county to the north and east, the wells keep within these same limits, the depth varying with the elevation. Pumphreys, with wells varying from 10 to 105 feet, offers as wide a variation as any. Linthicum is about the same. Frequently water is found at two levels even in comparatively shallow wells. For instance, on the high levels around Brooklyn, water is often found at 30 to 35 feet, but this supply is uncertain and most of the inhabitants find it necessary to sink their wells to 50 or 60 feet where a dependable supply is found.

Conditions are very similar in the western part of the county. Along the ridge to the west of Harman's the wells run about 40 feet deep. If, however, a well is begun on an Arundel surface this must be pierced before water can be obtained, since the Arundel is essentially a clay formation throughout and has no water-bearing horizon. An instance of this was noted 1 mile east of Patapsco Station, where, at a house located near the summit of the Arundel formation, a well had at the time of the writer's visit been dug through over 90 feet of solid clay without reaching water. The lower down in the Arundel surface a well is begun the less the depth which must be penetrated, for the Patuxent formation directly below is an important water carrier.

ARTESIAN WELLS

Waters of the Potomac Group

The waters carried by the Potomac formations are doubtless the most important of the county, and are the most widely utilized. These have been most thoroughly prospected by the Brooklyn and Curtis Bay Light and Water Company, which has a series of wells ranging from 109 to 400 feet. One well passed through water-bearing horizons at 180 and 200 feet, but found its principal source at 337½ feet. Another well nearby is 575 feet deep. At 300 feet it struck a little dirty water; at 375 feet bed-rock is thought to have been encountered; continuing in this to 575 feet no water was found. This makes it improbable that the crystalline rocks are good water-carriers in this area. The horizon at the base of the Potomac is uncertain, but several horizons are found in the group which bear water. The experience of the water company shows that conditions are favorable to finding a supply between 100 and 200 feet, although failures occur. A series of wells at East Brooklyn from 100 to 375 feet all found good supplies of water at points ranging betwen these depths. A well at Seawall, 562 feet deep, procured no water; yet one at Fort Armistead, Hawkins Point, 572 feet deep, pumps 3000 gallons per minute. Both of these wells must have reached the horizon at the base of the Potomac group and give further indication of the pockety nature of the water. At Eastport, wells at 208 and 218 feet gave a good supply with a flow of 50 gallons per minute

from the shallower one. A well at Bay Ridge, east of Annapolis, yielded water from the middle Potomac at 470 feet. This water was sulphurous and irony, but the record is valuable in that it shows the presence beneath a large area in the northeast section of the county of a fairly constant supply of water from the Potomac beds at moderate depths. About midway between these areas is a well at Round Bay which yielded a strong flow of somewhat irony though not disagreeable water at 225 feet. It is to be borne in mind that all these wells are located close to sea level, and that at higher elevations borings would have to be deeper and flows could not be expected. The records show the source of these waters to be usually a sand and gravel bed. Often the occurrence of a clay cover is noted.

Waters of the Upper Cretaceous

The Magothy is the chief water-carrier of the Upper Cretaceous. Flowing wells at Annapolis are said to have reached this horizon at about 200 feet.[1] The writer visited a well on Luce Creek, Severn River, just as boring operations were being completed. A good flow was obtained at 135 feet from material which was undoubtedly Magothy. Calculating from the dip per mile, this is doubtless the same horizon which was water-bearing at Annapolis. The general relations of the Magothy should make it a good water carrier wherever its sandy phase is penetrated. Water should therefore be obtained along the line of strike at depths corresponding to the above plus additional altitude. The depth to which borings must go increases 25 to 30 feet per mile to the southeast. Water from this same horizon or from the Raritan was obtained in a 150-foot well at Revell. This water has a "marshy" taste, and so much iron was present as to make it useless. On standing, this oxidized and appeared as a red sediment. An impregnation with iron and sulphur is quite frequent in the Magothy, although the water may be very satisfactory at other times. The supply from this horizon, however, is more apt to be distasteful than that from the Potomac.

[1] Darton, N. H., U. S. Geol. Survey, Bull. 138, p. 127.

Waters of the Eocene

The waters of the Eocene are extensively utilized in the southern part of the county where these beds are covered by the younger formations and are not dissected by streams. Such an area is found in the general region of "The Swamp." There are over 30 flowing wells in this region ranging from 110 to 150 feet in depth. The flow is as a rule 8 to 10 gallons a minute, but is occasionally less, and is said to be decreasing slightly. The water-bearing horizon seems to be about midway in the Aquia. A well was sunk at Lothian to a depth of 300 feet, but no water was found except near the surface. This well, however, did not penetrate deep enough to test all the horizons from which "The Swamp" obtains its water. For instance, several wells at Galesville are 150 feet deep. To find this level the well at Lothian should have gone 320 feet as nearly as can be calculated. And to strike the horizon at Leitchs Wharf an even greater depth would have been required. These horizons, however, vary according to the amount of argillaceous matter locally developed in the Aquia, and it is impossible to tell, except at closely adjacent points, at just what depths water will be encountered.

Waters of the Miocene

The Miocene farther south yields copious supplies of artesian water. In Anne Arundel County it is usually too near the surface and too dissected to be productive, and so far as known no wells obtain water from this horizon. At North Chesapeake Beach, just over the line in Calvert County, a good flow of water was obtained from the Miocene at a depth of 85 feet.

BIOGRAPHY

Homer Payson Little was born at Columbia, Connecticut, on August 3, 1884. He early moved to Dalton, Massachusetts, and received his preliminary education in the public schools of that town, graduating from the High School in 1902. The next fall he entered Williams College where he followed a four years' course, receiving his A. B. in 1906. The fall of the same year he entered the Geological Department of The Johns Hopkins University. The third year there he was awarded the Scholarship of the Department, and in the fourth year the Fellowship. During the summer of 1907 he was engaged in work on the coals of Wyoming with a U. S. Geological Survey party; in 1908 he mapped the geology of Talbot and north Dorchester counties, Maryland, for the Choptank Folio, under the direction of B. L. Miller; in 1909 he mapped the geology of Anne Arundel County for the Maryland Geological Survey, and procured the material for the preceding dissertation.